DEPARTMENT OF THE INTERIOR, CANADA
HON. CHARLES STEWART, Minister W. W. CORY, Deputy Minister
GEODETIC SURVEY OF CANADA
NOEL OGILVIE, Superintendent

ANNUAL REPORT

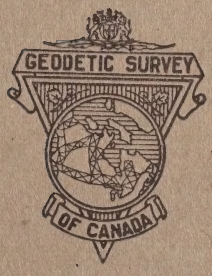
OF THE SUPERINTENDENT

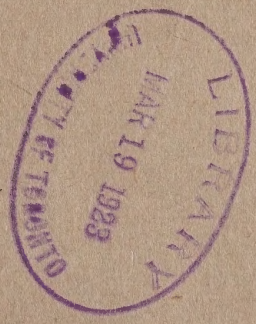
OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1922





OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1922

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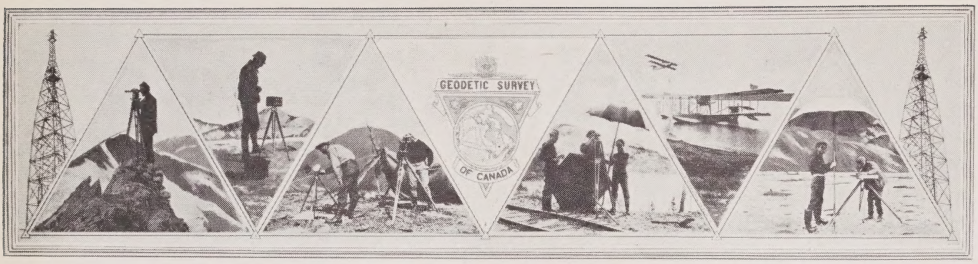


REPORT OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

Sir,—I have the honour to submit my fifth annual report of the operations of the Geodetic Survey of Canada, together with the attached summaries of reports of the engineers in charge of various sections of the work.

RESUME OF SEASON'S OPERATIONS

Geodetic operations, in various stages of progress, were carried on in eight of the nine provinces during the field season of 1921; triangulation and allied operations were prosecuted in all provinces except Saskatchewan and Prince Edward Island; precise levelling was carried on in British Columbia, Alberta, Saskatchewan and Ontario; city mapping was in progress in London, Ontario.

TRIANGULATION

British Columbia.—Triangulation operations were carried on in two districts in British Columbia—along the coast north of Vancouver island, and up the Fraser river.

The coast parties continued the angular measurements which are being carried northward from Vancouver to Prince Rupert. The section north of the north end of Vancouver island in which these parties were working in 1921 is one of the most difficult sections of the Dominion for triangulation, on account of the heavy rainfall and the prevalence of fog, and the progress was consequently slow. It is expected, however, that the worst area has been completed, and progress to Prince Rupert will be faster than has been possible during the last two seasons. This net of primary triangulation is of great value for hydrographic purposes and in co-ordinating the provincial land surveys along the coast and is part of an international co-operative scheme for triangulation control of western British Columbia, Yukon and Alaska. The detailed report of the engineer in charge begins on page 37.

A reconnaissance party did the initial work of selecting stations for a primary triangulation net up the Fraser river from Vancouver to Kamloops. An extension of this net eastward will eventually connect with the prairie triangulation in the vicinity of Calgary. No angular measurements were made during the season. Through the courteous and very hearty co-operation of the Air Board a hydroplane was very successfully used for carrying on this reconnaissance in a very economical and satisfactory manner (see pages 31 and 32 for a further report on the aerial operations and the report of the engineer in charge respectively).

Saskatchewan-Manitoba.—In the spring of 1921 an arrangement was made between the United States Coast and Geodetic Survey and the Geodetic Survey of Canada for co-operative action in extending a primary triangulation net along the 49th parallel International Boundary. This net will form a basis of all future triangulation work which may be required in the West. It was arranged that the United States organization was to take the section from the 109th meridian, southeast of Medicine Hat, to the Pacific ocean, while the Geodetic Survey of Canada undertook the section from the 109th meridian to lake of the Woods, a distance of about 625 miles.

The first step of selecting triangulation stations was undertaken last season (1921). Two parties completed the reconnaissance of about 500 miles during the season and plans were put under way for carrying on the completion of the reconnaissance, preparation of stations, building required towers and making the angular measurements of at least part of the section during the season of 1922. The comparatively short lines which are possible on the prairies (less than 25 miles), together with the prevailing clear weather and good transportation facilities, permitted very good progress to be made in 1921, and gave an indication that any required triangulation on the prairies will be inexpensive and quick. The report of the engineer in charge will be found on page 39, while a sketch of the reconnaissance scheme is shown on page 40.

Ontario.—City triangulation, angular measurement of primary triangulation and precise traverse comprised the operations in Western Ontario during the season of 1921.

A triangulation net embracing the city of Toronto and vicinity, based on the primary triangulation in that region was completed during the season. This net was required for the accurate mapping of the city and the cost was to a great extent borne by the city, this Survey furnishing only the engineer with his instruments. Toronto is the third city which has taken advantage of this co-operative arrangement, the others being Montreal and London; the triangulation of the cities of Halifax, St. John, Vancouver and New Westminster was done entirely by the Geodetic Survey in connection with our regular operations in those vicinities for other purposes.

The triangulation operations in the vicinity of lake Huron completed the primary operations of this Survey in that region. The triangulation has now been carried to the shore of lake Huron at a number of points for future use. See plan on page 43 and report of the engineer in charge on page 42.

The precise traverse party which operated in the vicinity of Simcoe, Ontario, had a similar function with regard to lake Erie, as the above mentioned triangulation had with respect to lake Huron. No points had been tied in on lake Erie for a distance of about 150 miles from Niagara Falls to a point south of Chatham, on account of the difficulty of extending triangulation to the shore of the lake. To supply this deficiency a precise traverse was run south from a triangulation station near Simcoe to lake Erie at Port Dover, thence northeastward to another triangulation station at Hamilton. For further information, see page 21 and the report of the engineer in charge on page 44.

Quebec.—Triangulation operations in the province of Quebec were confined almost entirely to the gulf of St. Lawrence.

A reconnaissance party revised the location of some of the stations in the base net at the west end of Anticosti island, then carried the main triangulation as far as Southwest point on the south side of the island, and along the channel between the north side of the Island and the North Shore as far as Watshishu and Charleton point, thus completing the reconnaissance of the western half of Anticosti island (see sketch on page 49). The North Shore is comparatively low from Seven Islands bay eastward for 350 miles, few elevations greater than 250 feet being available for triangulation stations. In this respect it is similar to Anticosti island but on the latter the land is rolling and timber covered; the shores of Gaspé on the contrary are high and abrupt, elevations of 1,000-2,500 feet within a mile or so of the shore being common, while in the interior the Shickshock mountains appear saw-tooth in form 2,000-

4,000 feet high when seen from the Gulf. On account of the low elevations available along the North Shore, it is impossible to see from Anticosti to the North Shore further east than Watshishu, and Charleton point, and further east the triangulation of the North Shore will have to be carried inland for a distance of 150 or 200 miles till the islands off shore and the high hills of Newfoundland can be utilized. The report of the engineer in charge of reconnaissance begins on page 48.

A tower building party was engaged for the full season building towers at triangulation stations along the Gaspé shore, and at the stations at the western end and along the south shore of Anticosti island.

Two angular measurement parties operated during the season. The reconnaissance party had established stations in 1920 and several lines were so long and the elevations of the terminal points so low that it was known that an exceptionally high coefficient of refraction would be required in order that the points would be intervisible. Everything was done to determine what coefficient of refraction might be expected, and it was reasonably expected that these lines would be open. There was an element of doubt about the matter, which was satisfactorily dispelled only when observations were—with difficulty—made over these lines which passed very close to the surface of the water.

The island of Anticosti is about 140 miles long with an average width of about 20 miles. The land is rolling and covered with a dense growth of timber. The backbone of the island lies close to the north shore and rises to a height of 200–400 feet; from this backbone the land slopes gradually to the south side. The island is privately owned and has been stocked with wild life of all kinds, which has increased to a remarkable extent under the strict protection which it has received. Lumbering and pulp operations have been carried on at the western end of the island and for this purpose a standard gauge railroad some 20 miles long was built. This railway made the transportation problems at the west end of the island much less difficult. The Geodetic Survey is greatly indebted to the Anticosti Administration for their kindness in facilitating its triangulation operations in every possible manner.

The C.G.S. "*Gulnare*" was indispensable in carrying out all of the operations on the gulf of St. Lawrence. See page 48 for the report of the engineer in charge of these operations.

Later in the season the New Brunswick reconnaissance party was transferred to the Saguenay river and was engaged in preparing stations on the lower Saguenay triangulation.

During the fall of 1921 and spring of 1922 some twenty points were located by triangulation and traverse and their elevations determined in the hills north of Ottawa. This information is being used in connection with experimental aerial surveys in the district by the Air Board, which, with its advisors, is working towards the development of a mechanical apparatus for plotting from air photographs.

New Brunswick.—The reconnaissance survey along the east coast of New Brunswick from the bay of Fundy to Chaleur bay was completed during 1921. It is anticipated that tower building will be commenced in 1922 to prepare the selected stations for the angular measurements, which then can be made in 1923. This triangulation will be extended around the Gaspé peninsula to connect with the St. Lawrence River triangulation.

This reconnaissance has been of excellent service to the Forest Service of New Brunswick in laying out a scheme of fire look-out towers, as the requirements of the two organizations are very similar in respect to the towers. See page 12 for other information regarding a co-operative plan of tower building for the two organizations.

Nova Scotia.—During the season of 1921 the previous year's work was continued by one reconnaissance party, one tower building party and two direction measurement parties. The season of 1921 marked the completion of some of the main purposes of our triangulation in eastern Nova Scotia; the triangulation was completed to the Sydney vicinity and the principal lighthouses and church spires along the

coast from the Strait of Canso to north of Sydney have been located for control points for hydrographic and militia topographic surveys. The remaining operations in this area comprise the connection of the Magdalen islands and Newfoundland with the mainland. It is anticipated that this work will be completed in 1922.

Detailed reports by the engineers in charge of this work begin on pages 57 and 60.

STANDARDS

The standardization of the five fifty-metre invar tapes of the Geodetic Survey has been made as usual both before and after use in the field. Three of these tapes are used exclusively for base line operations, a fourth was employed on the precise traverse work in western Ontario, while the fifth known as No. 4252 is kept as a reference tape. The standard of length of the survey is the standard nickel bar No. 10239 at 0°C.

As intimated in the last annual report an investigation of the behavior of precise level rods under different atmospheric conditions has been carried on. These rods made of pine are boiled in paraffin to make them immune from the effects of humidity. The experiments conducted during 1921 serve to show that the rods still continue to lengthen or shorten as the humidity of the atmosphere increases or decreases. This investigation will be continued during the coming summer but the results already obtained should discourage the use of these wooden rods. Invar strips are now in possession of the Survey, and they will be standardized and graduated to replace the wooden rods for precise level work. For detailed report see page 68.

BASE LINES

The Anticosti Base Line referred to in the report of 1920-21 was prepared and measured during the year. This base line is nearly twelve and a half kilometres (7¾ miles) long, and will serve as a splendid control for the scale of the triangulation on the lower St. Lawrence river and gulf. Details of the operations are given on page 69.

GEODETIC ASTRONOMY

Two Laplace stations, West Base on Anticosti Island, and Derby in the Cape Breton triangulation net, were occupied during the season of 1921, also the azimuth of the line Cap-Chat to Castor on the St. Lawrence triangulation was observed. These Laplace determinations control the twist of the triangulation. See page 67 for detailed report of the engineer in charge.

PRECISE LEVELLING

In the fiscal year 1921-22, 985 miles of precise levelling was added to the level net, making the total amount to date 15,016 miles. Three hundred and eighty-four permanent bench-marks were established, bringing the total number at the present time to 4,544.

The report of the Supervisor of Levelling and reports in detail by the engineers in charge of the field parties will be found on pages 61 to 66.

CITY MAPPING

The city mapping of London, Ont., was continued in 1921, the work being concentrated principally on the traverse and secondary level nets, which now cover nearly all the area within the city limits. In addition enough details were measured to plot four map sheets covering an area 4,000 feet by 6,000 feet.

Canada suffers very considerably from the absence of accurate contoured maps, prepared by a central authority on a uniform scale and system. From the experience in Canada and other countries, there seems to be no practical way in which maps can be prepared by municipalities, if successful results are to be obtained. Map making is a science in itself and can only be economically conducted by engineers specially trained in both field and office methods. All over the world it is

recognized that as our social system becomes more complicated, the need for exact knowledge grows in an increasing ratio; also the need is greatest where the population is densest. The following extracts from official reports show how India, South Africa and Great Britain are preparing to meet, or have met, the growing demand for accurate large scale city maps.

In India:

> Formerly it was the practice for the Survey of India to survey all important towns falling within the area allotted to a topographical survey party, to be made on a six-inch or twelve-inch scale. Although this practice has been abandoned for many years, the old maps on these scales of a large number of towns are still stocked and issued.
>
> At the time when most of the old town surveys were made, general maps of the towns, on scales of six or twelve inches to one mile, were all that were required for government or municipal administration, but in recent years, *a demand for large scale plans showing dimensions as small as a few feet has arisen.*
>
> The survey of towns and the preparation of town plans are not now part of the normal duties of the Survey of India, but are usually carried out by the municipalities concerned, with the aid of some retired officer of the Department. *The former system is not always entirely satisfactory,* and it is possible that the preparation of certain town plans may, in the future, be allotted to the Survey of India. In the case of the *important large scale survey of Bombay, now in progress, an accurate traverse framework has been made by the Survey of India.*

A later report shows that the Survey of India is now actively preparing to put the new policy of city mapping into force. In August, 1919, Colonel E. A. Tandy, R.E., of the Survey of India, drew up a definite proposal to experiment in making large scale town maps by the assistance of aerial photographs. The city of Agra was chosen, and the experiment carried out in February and March, 1920. It is described in brief by Major C. G. Lewis, R.E., as follows:—

> Aerial photographs are to be taken of the city and a mosaic compiled from the contact prints. The mosaic is to be used for reconnaissance chart for the triangulation scheme which is to fix six points per ten acres; this constitutes the first season's work. For the next season's work the photographs are rectified and enlarged to a scale of 1-900 and mounted upon bristol board; these are taken into the field and all necessary street and other detail drawn in upon them. Levelling for placing bench-marks and contouring is to be carried on at the same time. From the combined detail, from triangulation, levels, measured detail and photographs the map is to be constructed.

Colonel Robertson, in his paper on "The Practice of Town Surveys," was of the opinion that the scale of Indian towns should not be larger than 1-500, while the scale of 1-1000 would probably meet all requirements.

In South Africa a Survey Commission was appointed by His Royal Highness the Governor General, to inquire into matters concerning the survey of land. The report* of the Commission, dated July 5, 1921, in regard to City Surveys says in part:—

> The lack of reliable town plans is the cause of much expense to municipalities and to citizens. The City Engineer of Cape Town stated that for lack of a proper survey of the city we have to go on re-surveying and re-surveying for all purposes connected with lawsuits, claims against the municipality and such like. Administrative work for lack of a satisfactory town plan, is also made more expensive . . . . Your commission is strongly of opinion that municipalities should be given power to carry out a re-survey of their areas, and that the cost should be divided equally between the Government and the Municipality.

*See other quotations from the report of the South Africa Commissioin beginning on page 19

In Great Britain, the Government, as a national authority, conceive their duty to be to have an accurate map of the country, and they limit themselves to carrying out that duty. They do not ask the cities to bear any portion of the cost, and they do not find that the preparation of such maps carries with it any responsibility for doing anything other than preparing and publishing the maps. The Ordnance Survey of Great Britain has mapped all the cities and towns in England, Wales, Scotland and Ireland on large scales of 1-500 and 1-1056. Revision surveys of towns are carried out by the Ordnance Survey at the request of the city and at its expense.

Successful experiments have been carried out by the Geodetic Survey in regard to cheapening the cost of city maps by the use of aerial photos; they are described in detail in the report of the Supervisor of Topography, beginning on page 25. The report of the engineer in charge of the City of London survey commences on page 29.

CO-OPERATIVE FEATURES OF YEAR'S OPERATIONS

Three main co-operative features have marked the 1921 operations of the Geodetic Survey of Canada, in addition to the increasing co-operation which is in evidence between this Survey and other Federal organizations. These features, as all co-operative movements should, have resulted in economy in and the increased usefulness of these operations.

The first of these features is one predicted in my last annual report and deals with general co-operation with the United States Coast and Geodetic Survey, and more particularly in the arrangement by which primary triangulation is being projected along the 49th parallel from lake of the Woods to the Pacific ocean as a co-operative measure by the two national geodetic surveys.

Under this agreement the operation on the total distance of about 1,250 miles was divided between the two organizations, the United States survey taking the western, and this survey the eastern half. Had this arrangement not been made it was the intention of the United States organization to extend an east and west triangulation net a short distance south of the boundary, while a similar east and west net not far north of the boundary had been on the programme of this survey since its inception. (See reference on page 18, and the map, facing page 18).

One net triangulation along the boundary would obviously serve the purposes of both countries almost as well as separate schemes; at least the economy of the co-ordination was self-evident, so that the above arrangement was made in 1921 and two Canadian reconnaissance parties took the field at once to lay out the scheme of the Canadian section.

Other reference is made to this work on pages 18 and 39.

Mention has been made in previous reports of similar co-operation between these two organizations. Along the Pacific coast, the two organizations are working on a co-ordinated scheme of triangulation through northern United States, British Columbia, south eastern Alaska, Yukon and the main part of Alaska, which will take a number of years to complete. Another net is that along the International Boundary from lake Superior to lake of the Woods. The Canadian half of this section was finished in 1917 and the United States share from about the 92nd meridian to lake of the Woods is in progress.

It is also to be noted that lines of precise levels which have been run by the national geodetic organizations of the United States and Canada will strengthen the precise level nets of the two countries.

The second co-operative aspect is in connection with the provincial forest services of New Brunswick and Quebec, with which agreements have been made for a division of the cost of towers which are required by this Survey on certain triangulation stations to obtain the necessary intervisibility of stations, and by the forest services as look-out towers for the detection and localization of forest fires.

FOREST FIRE LOOKOUT TOWER AT TRIANGULATION STATION

This Tower, eighty feet high, was built by the New Brunswick Forest Service to plans which made it suitable for a triangulation station tower. Note the inner tripod for supporting the triangulation theodolites. The cost of this tower was divided between the Forest Service and the Geodetic Survey of Canada. See reference pages 10 and 12.

Triangulation Tower on Anticosti Island, Gulf of St. Lawrence. Raising the first side of the inner tripod of a tower built of rough timber, cut locally.

Where a triangulation net is projected a reconnaissance party is sent out to select the required stations and determine the height of tower required for purposes of intervisibility of stations. If this Survey is not prepared to proceed at once with building these towers the forest services may erect those which it requires to plans mutually suitable to the two organizations, half the cost being borne by this Survey. In the case of those built by the Geodetic Survey and selected for their use, the province remits half the cost of construction to this Survey.

This arrangement is advantageous to the provinces concerned where the building programmes of the two organizations coincide, as the stations selected for geodetic purposes are in general admirably suited for the location of fire detection towers; hence, the cost of reconnaissance is saved. It is advantageous to both organizations in that one tower serves two purposes and the cost of both operations is thereby reduced.

To the end of the fiscal year 1921-22 only two towers have been built under these agreements, both being constructed by the Forest Service of New Brunswick in the north-eastern counties of Gloucester and Northumberland. It is expected that other towers will be constructed in 1922 both in New Brunswick and Quebec.

The third co-operative feature is that whereby the triangulation and precise levelling required in cities and their vicinities, for the production of city maps and plans, is carried on by the Geodetic Survey. The Survey provides the engineer and his instruments, while the city concerned pays for all materials, labour, etc., in connection with this work. It is found that city engineering staffs are generally insufficiently provided, both by training and lack of suitable instruments, to undertake this control work efficiently; hence it was desirable that arrangements be made whereby the one organization in Canada which is specially trained in these operations —the Geodetic Survey—could assist the cities in the ground work at least, of this very important work.

OF WHAT USE IS THE GEODETIC SURVEY?—WHAT OTHERS THINK ABOUT IT

The Geodetic Survey of Canada was established by Order in Council, P.C. 766, dated 20th April, 1909. In the words of the Order in Council its function was:—

to determine with the highest attainable accuracy the positions of points throughout the country, and the lengths and directions of lines, which may form the basis of surveys for all purposes, topographical, engineering or cadastral, and thereby assist in the survey work carried on by other Departments of the Dominion Government, by the Provincial Governments, and by municipalities, private persons or corporations. The operations also include a considerable length of lines of precise levelling

The establishment of the Geodetic Survey was then recommended for the following reasons:—

the operations so far carried on have shown that this accurate basis for surveys of all kinds can be provided for at a reasonable cost and .... the value of such work is universally admitted, being vouched for by world-wide experience.

To afford an idea of the economic value and of the use which is being made of the data obtained by this Survey, it is proposed to give extracts from a few of the letters received, which show the remarkably wide-spread use of triangulation and precise levelling data by Federal and Provincial departments, by municipalities, corporations and private persons throughout Canada, and which illustrate that the information has extensive economic value, quite apart from the scientific problems which may be solved. Only a few representative letters can be quoted on account of the space which would be occupied and because many of the communications do not admit of brief extractions.

Commencing with Federal departments, the Public Works Department had investigations to make in 1919 regarding conditions of navigation on the Fraser river,

B.C., and requested the Geological Survey to undertake a topographical survey of the region. The Geodetic Survey was asked to co-operate in this work in the following terms:—

We appreciate that your Department has the facilities for undertaking this work of precise levelling and triangulation to an extent to which this Department does not attempt, so that co-operation in this sense would result in there being no unnecessary duplication of effort and expense .... We feel that the information will be of value to this Department, not only in the present work, but it will educate our Engineers to make use of the valuable assistance which is available in other departments.

At the completion of this work the Geological Survey expressed its appreciation thus:—

Let me take this opportunity of expressing our appreciation of the valuable work done by the Geodetic Survey in establishing a primary control (triangulation) and bench-marks by precise levelling, in connection with the topographic work for the Fraser River investigation.

The Public Works Department required a basis for their waterfront surveys of the harbour of Port Arthur and Fort William, Ont., and in requesting that this basis be provided by the triangulation of the Geodetic Survey, describes its utility as follows:—

If this were done the Department would have an authorized starting point to which all work of any nature whatever affecting both Harbours could be referred, thus simplifying matters very much and avoiding many needless complications.

And from the same department illustrating the need for precise levels:—

Could you arrange to establish a bench-mark within a short distance of the water front at each of the more important places on lake Ontario, so that from these bench-marks we might be able to establish more readily the elevations of our low water level for lake Ontario and in this way be sure that the datum plane was the same at each of these places.

The Geological Survey has consistently used the triangulation and precise levelling data of this Survey as the primary control for its mapping operations in all sections of the country where the data have been available. In fact, all the mapping and engineering departments of the Federal Government have been, and are, supporters of an aggressive policy in the extension of triangulation and precise levelling into sections of the country which are to be mapped, or in which important engineering investigations are being undertaken.

The Militia Department, through its Geographical Section, does a considerable amount of topographical mapping in various parts of Canada. The following extract from a letter is representative of the feelings and requirements of that department regarding triangulation:—

In order that these surveys may be accurately connected with other Canadian surveys, and to correct errors that may exist in the work carried out by the Survey Division, it is very desirable that they should be connected with the triangulation points established by the Canadian Geodetic Survey. I have the honour, therefore, to request that—if possible to do so—the triangulation work of the Geodetic Survey be extended at an early date from New Brunswick to the two districts in Nova Scotia mentioned above (Halifax and Sydney) for the reasons already given.

while the following sentences indicate the value of precise levelling information to the Militia Department:—

....these publications (on precise levelling) are of the utmost service to this Department. .... The information contained there is invaluable to us ....

These accurate bench-marks will be of the greatest assistance in our topographic work in this district (Western Ontario).

The Hydrographic Survey of the Department of the Naval Service has made good use of our triangulation data both as primary control for new Hydrographic surveys and also in compiling the results of older surveys:—

As I am compiling a general chart of lake Ontario (one request says), I would ask you to be kind enough to send me at your earliest convenience the latest positions of all the points which have been determined along and near the shores of lake Ontario from Kingston to Niagara river, on the North American Datum.

Another letter says that the position of the lighthouse at the south end of the Queen Charlotte islands, as marked on the charts, is considerably in error, and adds:—

Would it be possible for the Geodetic Survey to undertake a triangulation of the Queen Charlotte islands, including the west coast .... as I am continually being asked when we are going to survey the west coast of the Queen Charlotte islands, and nothing satisfactory can be done by ship triangulation .... on account of the difficulty of landing with the exposed coast and heavy ocean swell ....; we want something that will be determined for all time.

A later letter, in describing the prospective programme of hydrographic surveys in the waters of the gulf of St. Lawrence, the Atlantic ocean and the bay of Fundy, along the coast lines of Quebec and the Maritime provinces—surveys which are so vital to safe navigation of Canadian waters, and which must be adequate to suit the requirements of our increasingly important trade routes—thus shows the part which the Geodetic Survey should play in this essential work:—

If, therefore, the Geodetic Survey can find it convenient, it will be of great assistance to this Survey (Hydrographic) if points, about twenty miles apart, could be established in the area I have just outlined .. .. If it is not convenient for the Geodetic Survey to carry on this work at the present time, the Hydrographic Survey can carry on, but, of course, time taken up with the larger triangulation will be so much lost time in the Hydrographic work.

It is, of course, well known that certain automatic tide gauges of the Tidal and Current Survey, Department of the Naval Service, furnish the datum (mean sea-level) of the Geodetic Survey's system of precise levelling. The following extract of a letter from that Survey is interesting in showing the mutual benefit derived from the co-operation of the two Surveys:—

Continuous levels around the two arms of the Bay of Fundy would enable the elevation reached by extreme tides, which have been observed during many years by the Tidal Survey, to be known at all points. This would be of much service in regions where there are such extensive dyked marshes, or hay lands protected from the sea. The result would be achieved if the bench-marks established by the Tidal Survey were connected with your Geodetic system.

A more recent use for triangulation data has been in connection with aerial photographic mapping, both by governmental departments and private corporations. One letter states that:—

the Air Board has arranged to take photographs of Montreal which are to be assembled to form a mosaic .... In order to regulate the scale I would like to have the co-ordinates of the various stations established by the Geodetic Survey within the city.

The above reference alludes to a triangulation of Montreal and vicinity, the purpose of which was to control the accuracy of a topographic survey which is being made by the city. The city of Montreal shared in the cost of this triangulation. (See also further reference to this survey on page 16).

The Chief Geographer of the Interior Department has had need of all the triangulation data obtained by this Survey in all parts of Canada, and a typical sample of his requirements is shown in an extract from a letter which says:—

I am preparing a map of Vancouver island, including the coast of British Columbia and part of the district of Vancouver, and I would be pleased to obtain from you results of all triangulation work through Queen Charlotte sound and the strait of Georgia.

The needs of the Chief Geographer are kept in mind by all our triangulation parties and the particular requirements of his work are given special attention.

The inadequacy of railway levels for supplying general levelling information, and the value of precise levelling in making this information most useful is shown in a letter which was received from the Commission of Conservation, under whose auspices a publication on "Altitudes in Canada" was issued.

If it is possible to do so without inconvenience I trust that you will be able to run a line (of precise levels) this summer from Napinka to McCreary, Manitoba .... Such a line would be of very great assistance in determining the errors that have crept into the railway levels at various points along this line.

Interprovincial Boundary surveys also find the triangulation of this Survey of great assistance, the needs of the Alberta-British Columbia Boundary Commission being stated as follows:—

It would be a very great help towards keeping within known limits of accuracy were you able to assist the Boundary Survey as indicated above (the establishment of a system of triangulation to extend northward from the Canadian National Railway at the Yellowhead Pass to the last intersection of the 120th Meridian and the Continental Watershed).

Among the most energetic supporters of systematic triangulation by the Geodetic Survey are a number of the provincial survey organizations, as is shown by extracts from a few letters from these departments. Quebec, British Columbia and Ontario especially require triangulation information, as they are, perhaps, more assiduous in map making than other provincial organizations. The Surveyor General of the Department of Lands of British Columbia writes:—

.... you can readily understand the value to this Department of proper geodetic control to our secondary triangulation.

and in another letter says:—

it is hoped that we will be able to tie the majority of these positions (primary triangulation stations) to our lot surveys, and so have the benefit of your precise work.

From the Ontario Department of Lands and Forests comes the following regarding the triangulation of the Geodetic Survey:—

As geographic control in all parts of Canada is of national concern and is one of the principal functions of the Geodetic Survey, I would submit the following programme of triangulation for your consideration, to be undertaken .... in this province as may be found possible .... You may rest assured that the operations of the Geodetic Survey are appreciated by this Department, and that we will do all in our power to make them of lasting benefit to our part of Canada.

An official from the Hydro Electric Power Commisson writes as follows:—

If it would be possible for you to let us have a list of bench-marks between Morrisburg and Cornwall, it would save us a lot of unnecessary labour in running precise levels which we need for the automatic gauges we are placing.

The Department of Lands and Forests of the province of Quebec, when requesting triangulation surveys up the Saguenay river gives a specific reason for requesting triangulation in that area:—

this present request is made in view of the fact that we are having a new map of the northern portion of Quebec prepared on a pretty large scale;

it bases its requests for geodetic triangulation in several other regions on the following arguments:—

Such work as the accurate determination of the positions of points by means of triangulation, by which the accuracy of our land surveys may be controlled is, as you know, a class of work peculiar to the operations of your Geodetic branch. Inasmuch as the work of securing the necessary field data of triangulation and precise levelling for geographic purposes over Canada, is work of the character for which your Geodetic Survey was commenced and as direct public service would result from the performance of such work up the Saguenay, St. Maurice and other rivers, I would ask if you could arrange that some of the work above suggested be commenced in the near future by your Geodetic Survey branch.

The procedure by which the triangulation is employed by the Quebec department is shown by the following extracts from letters:—

These (triangulation) stations will certainly be of great importance to us and we will give instructions .... to connect each of these points with some well known and defined points of our survey .... this Department is co-operating with you in making the best use of your data by connecting their surveying and mapping operations to your triangulation stations wherever available .... the usefulness of the triangulation of the Geodetic Survey of Canada in controlling the geographic operations in the province of Quebec is well realized by the Department of Lands and Forests.

The Chief Engineer of one of the Manitoba Government Departments writes:—

We are using your bench-marks as a base wherever possible and will eventually have a fairly comprehensive scheme of levels in the Province. A knowledge of your proposed work this summer would .... give us a more exact line of bench-marks than we would be able to establish in the same territory.

A natural development of the triangulation of the Geodetic Survey is the use made of it by the forest services of the Dominion and the provinces in locating fire look-out stations. As the triangulation stations are necessarily located on the highest points in their vicinities, and as lines of sight are generally open in all directions, a considerable amount of labour is saved the forest services by using our triangulation nets as a basis for the location of their fire look-outs. The Provincial Forester of New Brunswick writes:—

I appreciate very much your promptness in sending me the map with the information on it, which will prove of immense value to us in locating our look-out stations ... The map you have given us certainly eliminates a great deal of work in preparing a proper look-out scheme for this province.

Both New Brunswick and Quebec are operating under agreements with the Geodetic Survey for a division of the cost of towers erected for the joint use of the organizations. The Quebec Forest Service says:—

this Department would be pleased to co-operate with the Geodetic Survey in the expense of building observation towers, where such towers are so situated as to be of value to us.

The Forestry Branch of the Dominion Government explains the use of our triangulation stations for forestry purposes in the following words:—

These look-out points, as you are aware, are of very great use to us in connection with our fire protection system, as by them, in certain sections of the Railway Belt, the function of fire detection is almost exclusively served. The question of their precise location is, therefore, of very considerable importance.

As would be expected precise levelling is particularly appreciated by the great railway systems of Canada. An official of the Canadian Pacific Railway writes:—

I would like to know if these publications (on precise levelling) are on sale, and how to procure them, say in quantities of twenty-five, as I think the information given would be very useful to our District and Division Engineers.

while the needs of the Canadian National Railway are typified by the following extracts:

I shall be glad to have what information you can give me regarding bench-marks between Moncton and St. John, as we are particularly anxious to obtain this information for our records here (at Moncton).

.....

Would you kindly forward me, as soon as possible, all the publications giving the results of precise levelling .... If you could keep my name on your mailing list for future publications I would be much obliged.

All cities and municipalities—in the words of the city of Montreal:—

have found increasing need for an adequate topographic map, in connection with the engineering problems of this City, a need which will be felt still more when further expansion takes place ... We are commencing a survey of the City at once and are confronted by the absence of accurately determined points on which to base our operations ....

and the above letters adds:—

as triangulation, accurate levelling, etc., are functions of your Geodetic Survey .... we, therefore, respectfully ask to have the work outlined performed by your Geodetic Survey branch.

An arrangement was made whereby the cost of the above city triangulation was divided between the city of Montreal and the Geodetic Survey, and since 1919, when the above work was carried out, a number of cities have availed themselves of similar facilities. In requesting preliminary values of some of the results of this triangulation the engineer in charge at Montreal wrote:—

We are making a survey of Sherbrooke St., from Papineau Ave., to the eastern city limits, a distance of over six miles, where property lines are not well established. It would reduce this work to about one-half if we could have from you the co-ordinates of three points in your triangulation ....

One of the services rendered by the triangulation of cities is mentioned in a letter from the Essex Border Utilities Commission, which states:—

a desire to procure the co-ordinates of any existing triangulation points in order that we might plot them accurately and use them as a control in assembling the many partial maps we have of the district.

A previous letter had expressed the appreciation of our expectation:—

. . . . . to extend the work (triangulation) of your department in this vicinity, as, when available, it will be very useful to those engaged in engineering work.

The Assistant City Engineer of Vancouver in preparing a report of the Datum Plane Committee wrote:—

.... I should be glad to have particulars of any other bench-marks which you have established within twenty miles of Vancouver, and especially of those at Blaine, Washington, which connect with the American system of levels. I am preparing the final report of the Datum Plane Committee, and should like to include in it whatever particulars can be of service to engineers practising in the district.

A number of large lumber companies are energetically surveying their timber limits by aeroplane, and their great need is "ground control"; that is, points on the ground, the accurate relative positions of which are known, so that the scale of the resulting photographs can be regulated in making maps from the photographs. The secondary triangulation of the Geodetic Survey supplies this required ground control, so that it is natural that such firms as Price Brothers and Co., Ltd., should write:—

We would like to co-operate with you and be allowed to use your (triangulation) stations for ground control in making our aerial photographic survey of the Shipshaw drainage area (a tributary of the Saguenay river in Chicoutimi county, Quebec). We might be able to extend our aerial survey if co-operation with you can be secured.

One other instance of the assistance and value of our triangulation to corporations will be cited on account of the whole hearted appreciation which is shown of the value and economy of topographic mapping. In 1913-15 important topographic work was undertaken by the Geodetic Survey in the Thirtyone Mile Lake watershed and along the Gatineau river in the interests of "A Pure Water Supply for a Proposed Federal District of Ottawa". The triangulation of the Geodetic Survey was, of course, used as primary control for the maps which were produced. Copies of these maps were supplied to the Montreal Engineering Company, Ltd., which was acting for the Royal Securities Corporation in some investigations, and their letter of appreciation is given in full:—

I wish to acknowledge our appreciation of all the courtesies which you have extended to us.

In particular, I have reference to your information in regard to the 31-Mile Lake pipe line. This work has proved invaluable to us for many reasons. There has been no other accurate survey made of this region, and the only expression of regret we have to make is that this work was not carried out on both banks of the Gatineau.

The actual monetary saving to us, for the short section of your survey which we will possibly require, is in the neighbourhood of five thousand dollars, but it is impossible to estimate the indirect saving with which we may credit your work on account of the fact that there will be no high appreciation of property values, owing to our not having to put our own men on the ground in such places as we consider might have to be acquired.

Only one representative instance will be given of the many inquiries and requests for information which are received from private engineers. In this letter the difficulties under which private provincial surveyors' work is carried on are recorded, and the manner in which this surveyor believes that some of his should be solved. He writes:—

The reason I am making these inquiries is that the boundary marks of our Provincial Survey, which is the basis of our system of land tenure, are disappearing, and it is important that they should be linked up with some triangulation system permanently marked while there is yet time. The 'corner posts' of our Provincial Surveys are generally fir or cedar posts set in cairns which are liable to disappear.

THE TRIANGULATION PROGRAMME OF THE GEODETIC SURVEY OF CANADA

A milestone in systematic topographic mapping in Canada was passed in 1903 when Major E. H. Hills, C.M.G. (Royal Engineers), Head of the Topographical Section of the War Office, made a report on the Survey of Canada. After dealing with the great saving and economic advantages of a systematic topographic survey of Canada, Major Hills devoted one section to the main lines upon which a systematic survey of the Dominion should be undertaken, and for descriptive purposes the survey was divided into two parts, triangulation and detail or topographic survey.

While the lines recommended by Major Hills have not so far been followed very closely with respect to the topographic survey, in that a centralized organization and co-ordinated plan have not been evolved, the triangulation has followed very closely along the lines recommended, and it is interesting to show how the development of the triangulation as visualized by Major Hills has been followed since the organization of the Geodetic Survey in 1905 and how subsequent considerations have modified and (it is hoped) improved his original scheme.

Map 1 facing this page shows Major Hills' plan of the development of the triangulation for Canada, while Map 2 shows the triangulation completed or in progress in Canada up to the end of 1922, together with the programme of projected operations so far as this has been worked out. The completion of this programme will take quite a number of years, and changes will doubtless be made in some of the nets where topographic conditions and the needs of the country dictate.

It will be seen from a comparison of the two maps that the suggested programme of Major Hills is being followed in the main and that any changes have been either elaborations of his scheme as the uses of the triangulation have become more appreciated, or have been necessitated by the development of the country along lines not discernible in 1903 when the report was issued.

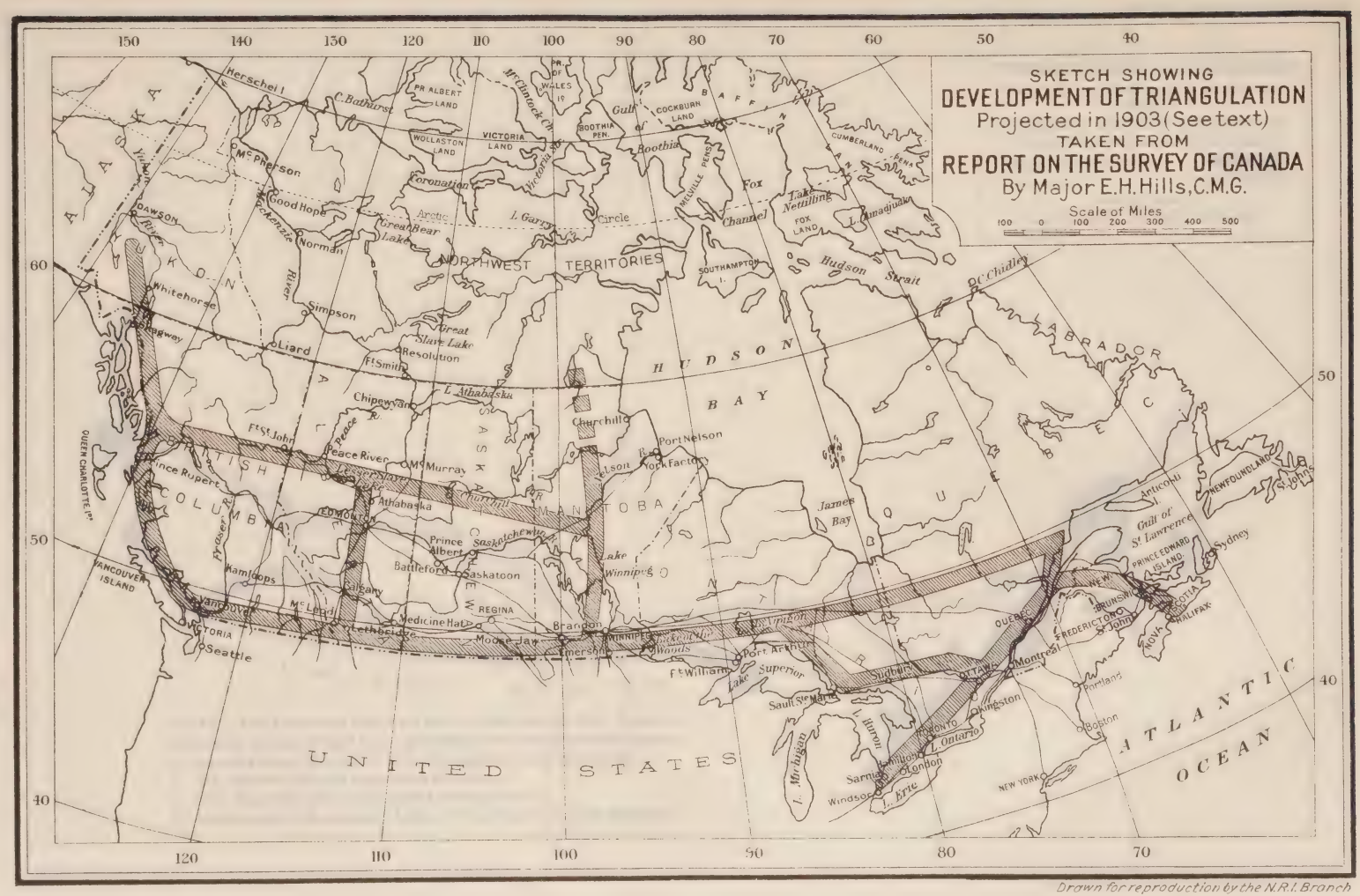
Some of the factors which have influenced and will influence the course of the triangulation in a different course to that outlined by Major Hills may be enumerated.

1. The surveys of our sea coasts and inland waterways require triangulation control, which means, where practicable, secondary triangulation checked at intervals by primary. This has necessitated more triangulation along our Atlantic seaboard than was predicted by Major Hills.

2. Co-operation of this Survey with the United States Coast and Geodetic Survey in the prosecution of triangulation which is of advantage to both countries has to some extent influenced the course of our programme with resulting economy to both countries. This is particularly noticeable along the 49th parallel International Boundary, where the triangulation at present being carried on bestrides the boundary, whereas Major Hills' proposals carried it north of it, and also along the coast of southeastern Alaska, where the United States triangulation has been substituted for Major Hills' programme through the inland mountainous country of British Columbia.

3. The presence of railways, such as the Transcontinental and Grand Trunk Pacific, which were built subsequent to the publication of Major Hills' report, has had a large effect on our prospective triangulation programme. Naturally operations are made easier where transportation facilities are better, and in addition railways generally denote settlement and development with the consequent greater necessity of geodetic control for mapping. This explains the changes of programme across the northerly settled parts of Canada from Quebec to Prince Rupert.

4. Requests for triangulation nets to control the geographic position of points on Interprovincial Boundaries have also had their influence on the programme of geodetic work as it has developed. Thus on Map 2 triangulation which is being started in 1922 up the Ottawa river will eventually touch the Ontario-Quebec boundary at a number of places as far north as James bay; a similar effect will be noted along



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the Alberta-British Columbia boundary, and the triangulation of the Gulf of St. Lawrence will provide geographic positions for possible future surveys of the Labrador-Quebec boundary.

5. In Major Hills' report triangulation was recommended along the 98th meridian, northward as far as possible from the International Boundary south of Winnipeg. In the projected triangulation shown on Map 2 this net does not appear.

In 1898 international co-operation by Canada was urged for the production of this work, it being claimed that measurement of this arc of a meridian by Mexico, United States and Canada was a work of great scientific value to the world for determining the figure of the earth, as well as of economic value to the countries directly concerned. This meridian runs about 100 miles west of Hudson bay and triangulation along it would be of comparatively little economic value to Canada at the present time on account of the (as yet) unsettled country through which it would pass, and it has been considered unwise to expend the energy of the Survey on this project, at least until the more settled portions of the Dominion have been adequately served. In addition to this consideration modern geodetic opinion seems to be that the "arc" method of deducing the figure of the earth is unnecessary and that, by the "area" method, the triangulation may be carried forward wherever and in whatever direction the topography and requirements of these operations make it desirable without detracting from the value of the triangulation for studies of the dimensions of the earth.*

For these reasons this work has been dropped from our programme of triangulation operations.

Major Hills' report provided an incentive to the development of systematic topographic surveys of Canada, and shows in a very convincing manner the practical and economic advantages which would accrue to any country which pursued a systematic and carefully co-ordinated policy of topographic mapping. A great deal still remains to be done in Canada before a proper co-ordination of the various map-making agencies and methods is accomplished. A great amount of survey work is being done in Canada by various agencies and for different purposes, but on account of the lack of co-ordination in all of this work, due partly to the division of authority between the federal and provincial governments, the country is paying more for a not entirely satisfactory result than it would pay for a systematic survey based on well ordered scientific methods, of which universal experience has demonstrated the value.

Speaking of this uneconomical practice in Canada, Major Hills said, in his report of 1903:—

> It cannot be doubted that similar waste of money has in the past occurred in Canada and will continue in the future, until the survey of the whole country is placed in the hands of a single expert survey department and prosecuted on sound methods.

Fortunately no lack of co-ordination now exists with regard to the triangulation, which, except for minor schemes of comparatively small extent, is being carried on solely by the Geodetic Survey of Canada, while the same policy is being aimed at with respect to precise levelling. Undoubtedly the uneconomical situation described above by Major Hills has been, and will continue to be, considerably reduced by the energetic extension of systematic triangulation and precise level nets by the Geodetic Survey.

SOUTH AFRICA'S EXPERIENCE AND CONCLUSIONS REGARDING THE PRACTICAL VALUE OF GEODETIC AND TOPOGRAPHIC SURVEYS

The exceeding practical value of the operations of the Geodetic Survey of Canada, and the lasting and increasing economy which will be obtained for the

* See U.S. Coast and Geodetic Survey publication, "The Figure of the Earth and Isostasy from Measurements in the United States", pages 169-170.

whole country by a rigorous prosecution of geodetic and topographic surveys in Canada received a recent confirmation from the experience of the Union of South Africa.

In January, 1921, a Survey Commission was appointed by His Royal Highness the Governor General of the Union of South Africa to enquire into matters concerning surveys. Among other matters on which the commission was required to report were included—

2. The extension throughout the Union of South Africa of—
   (*a*) the trigonometrical (geodetic) survey;
   (*b*) the connection as far as possible of farm beacons (land survey posts);
   (*c*) a topographical survey.

4. The establishment of a central office to control the trigonometrical and the topographic surveys, and the establishment of a Central Mapping Office.

16. The principles on which a new Survey Act and Regulations should be based, special reference being made to.....
   (*b*) the basing of all surveys as far as possible on the general triangulation.....

In numbers of places the report of the Commission shows that it was seized of the great importance of geodetic triangulation and topographic mapping in the economic development of the country. A few extracts will be given which show this very clearly:—

The history of the survey of a country follows the same course in every land. All governments experience the same difficulties in the first settlement—security of title and other advantages cannot be guaranteed, because the country is not properly surveyed; on the other hand the proper survey cannot be carried out because the land value does not justify the expense; hence, we find in every country initially the system of isolated surveys. As the country develops and the land becomes more valuable, the insecurity of the title, which results from the unscientific system of survey, leads to litigation about boundaries, ... and renders the civil and military administration of the country expensive and unsatisfactory. In the end the government of the country is compelled to establish a scientific system in order that the development be not retarded. .... The scientific system of survey rests on the main triangulation and the topographical survey of the country. .... There is one scientific system, and one only, viz: a system which rests on the main triangulation of the country. The triangulation gives a number of fixed points suitably distributed, and on to these points all smaller surveys should be joined. .... The main triangulation forms the fixed network, which, once laid down, persists for all time, and to it every other survey is attached .... Your commissioners wish to express satisfaction that the trigonometrical survey is being continued, and express the hope that with it will be combined topographic work. They are strongly of opinion that by doing this, ... the Government will be able efficiently and cheaply to do survey work which will enable suitable maps of South Africa to be published of value for irrigation, railway, geological, meteorological, defence, road-making, botanical and forest purposes. ....

In recommending the passing of a Survey Act, the Commission says that—

The Act should give power for basing all farm surveys, as far as possible, on the general triangulation. .... In surveys where all the conditions—including the connection with the main triangulation referred to in the last preceding paragraph—are complied with, the probability of error is reduced to a minimum. ....

Extracts from the summary of the Commission's recommendations are as follows:—

1. That the completion of the primary triangulation and the extension of the secondary and the tertiary triangulation in the more developed part of the Union be undertaken.
2. That the topographical survey of the Union be carried out and an immediate commencement be made.
3. That a central office be established to control the trigonometric and topographical surveys.

8. That wherever possible all cadastral surveys be based on the main triangulation.
25. That power be given for the proper body or person to carry on a re-survey of a . . . . municipality . . . . and that the cost of such survey be paid half by the Government, half by the public or owner concerned.
28. That a survey be not guaranteed, unless and until it is based on the main triangulation. . . . .

The value of precise levelling operations, such as have been an important part of the function of the Geodetic Survey of Canada since 1906 with very satisfactory results, is stressed by the Commission:—

A long-felt want is the lack of bench-marks of accurately known elevation, and the Commission advises the immediate survey of lines of high precision levels, connecting tidal stations at the coasts of the Atlantic and Indian oceans.

The conditions in South Africa are not identical with those in Canada with regard to topography and vegetal cover, so that methods which suit the one country may not apply exactly to the other; also, in Canada lands are administered largely by the provinces, so that responsibility for the accuracy of land surveys rests primarily with those provinces. The conclusion to be drawn from the above quotations are that geodetic and topographic surveys of Canada are not a luxury, the prosecution of which can be postponed with any economy; on the contrary, world-wide experience shows that they are one of the great necessities and most lasting investments which can be undertaken and prosecuted by Canada.

PRECISE OR PRIMARY TRAVERSE

During the past season a small party carried on the first precise traverse operation which has so far been undertaken by this Survey. From the results of the season's work the conclusion may be drawn that this method of precise measurement will have a useful place among the operations of the Geodetic Survey to supplement (or even to substitute for in certain cases) primary triangulation in districts where conditions are unfavourable for triangulation and favourable for traverse.

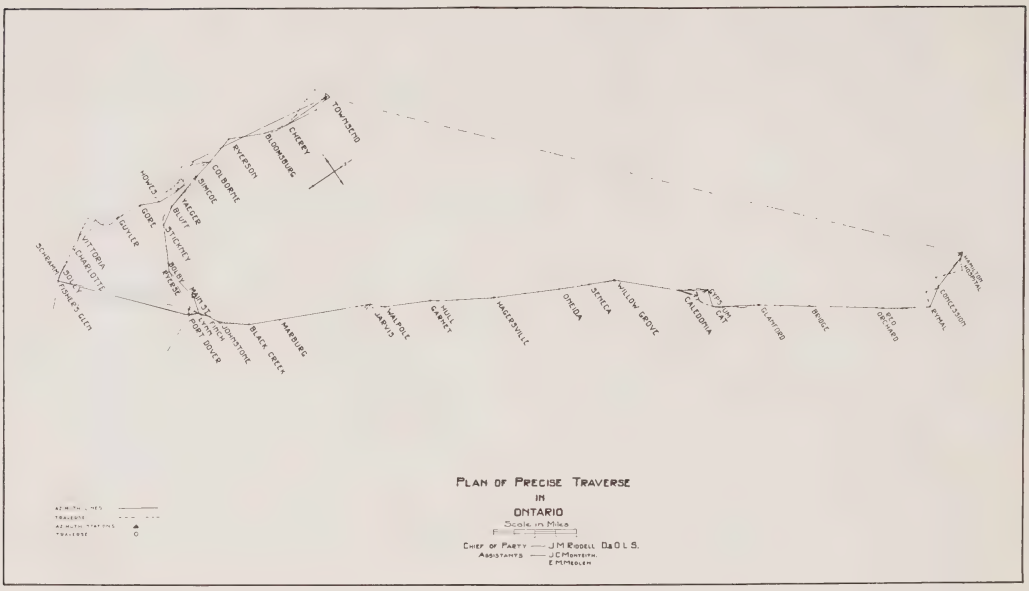
An economical and accurate substitute for primary triangulation is desirable in flat heavily wooded country traversed by roads or railroads, where the building of high towers makes the progress of primary triangulation slower and more uncertain and where the high cost of these operations becomes a serious factor.

The questions which made it debatable whether traverses could be economically run with the desired accuracy were as follows:—

1. Could direct measurement of distances be made accurately and with sufficient speed? It was known that the desired accuracy could be obtained if time and cost were not first considerations, as the measurement of base lines can be made with far more than the required accuracy. Hence the line of endeavour was to change the regular base line measurement methods so as to secure greater speed and economy, without lowering the attained accuracy below the required limits.

2. Could the angular measurement on the comparatively short sides of a traverse be made with an accuracy approaching that of primary triangulation? This feature can be taken care of by the use of the greatest caution in centering signals and instruments, and by carrying on azimuth line with sights as long as possible (a line which may or may not be coincident with, but whose length is controlled by, the measured traversed line).

The traverse lines are measured once with a 50-metre invar tape, the tension being applied by a spring balance; the centre line of a railway is used where feasible. The tape is standardized in a number of different ways, such as "on the flat" and supported at three and five points, for use under different circumstances. A check measurement is made with a steel tape to discover any large errors, such as those produced by a wrong count in the number of tape lengths. Slopes and temperatures are measured to make the required corrections.



It is to be noted that the use of steel tapes for precise measurements, except where frequent triangulation checks are provided, is almost useless. The impracticability of determining the true temperature and hence the length of the tape may produce errors of measurement of the order of 1 in 25,000, or $2\frac{1}{2}$ inches in a mile. The only method of minimizing such errors would be to make the measurements only on cloudy days or at night, which would of course not be feasible from an economic standpoint.

The angles of the main azimuth line are measured with a 12-inch theodolite such as is used for primary triangulation, while for those of the measured traverse line where this does not correspond to the azimuth line a repetition transit reading to 10″ is used, six repetitions of the angle and six of the explement being made.

For further explanation of the methods employed see the report of the engineer in charge, beginning page 44.

Respectfully submitted,

Noel Ogilvie,
Superintendent.

ADJUSTING OFFICE

W. M. Tobey, *Senior Geodetic Engineer*

The work of the adjusting office is summarized under the following heads:—

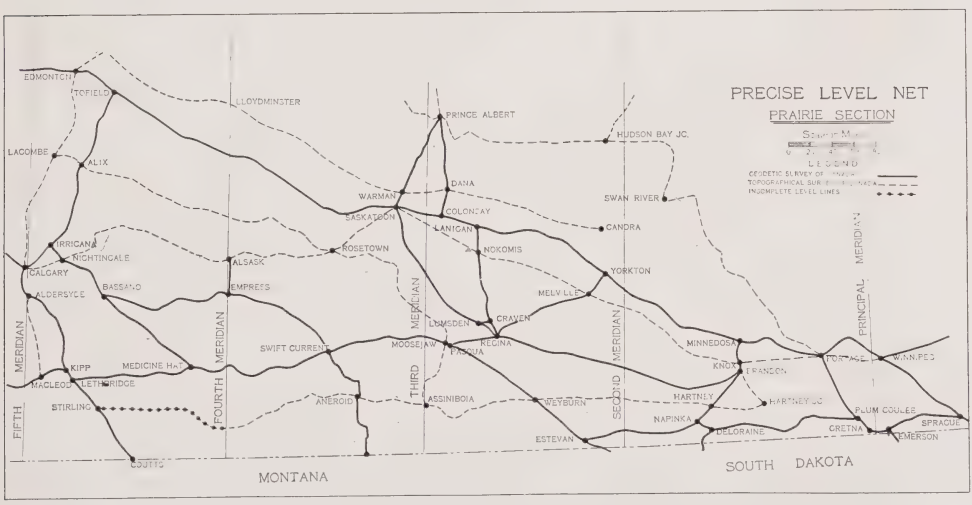
1. Field Inspection.
2. Refinement and Correction of Field Data.
3. Progress in the Adjustments (including level adjustment).
4. Determination of precision or probable accuracy of sides and other external parts of the triangulation or of a level net as advisory for new field work.
5. Determination of finished data; its necessity for engineers, surveyors and the general public.

1. FIELD INSPECTION

The general inspection of the field work was carried on this year by an analysis of the work submitted. By this means an attempt was made to cut out systematic errors and to find probable precisions of exterior parts of the triangulation. The *effects* of errors, at a distance from the source, must always be carefully studied. Any change in field work which the adjusting office may think necessary must always be considered as to how such change will amalgamate with the old work and as to what effect such amalgamation will have on distant parts of the work.

2. REFINEMENT AND CORRECTION OF FIELD DATA

The scope of the field inspection that needed especial care was confined principally to the British Columbia coast triangulation, the St. Lawrence River scheme and the primary traverse scheme of Eastern Ontario. The British Columbia coastal triangulation needs especial care and attention. The effect of propagation of errors throughout its length will continue to require the most careful consideration, and it is to be hoped that the theory of such effect of propagation of errors will be developed. This is a most pressing and necessary development as Briggs in "The Effects of Errors in Surveying" has pointed out, where he says his "work forms a contribution—for the most part new—to that study; its purpose is to investigate how errors combine in affecting the accuracy of surveys". In connection with the B. C. triangulation it is to be clearly understood that "left over" errors at the southern portion must have a serious effect on the northerly part of the triangulation and more serious as the triangulation gains headway, unless most probably controlled.



The reconnaissance work over the Fraser river as far as Shuswap lake by aerial navigation, not only emphasizes the utility and advantage of aerial work by covering many square miles in a season that would otherwise demand many seasons' work, but it emphasizes the importance such work will be to British Columbia generally.

The usual methods of testing the field data were employed. Only by a close scrutiny of the angle and side equations can an *accumulation* of field errors be prevented. To this end the angle and side equations were tested to see if they were of the required accuracy, the side equation test for primary work being that the

average correction given by the adjustment should not be greater than 0″·4. Secondary work was examined by similar methods.

During the year many descriptions of triangulation stations have been received and revised. These are essential to the public in recovering these stations. It is part of the duty of the cataloguer to see that such descriptions are so filed and indexed with other matter as to be readily available. An indexing of all matter under *name of station* has given excellent results.

Great emphasis must be placed on the proper relation of the reconnaissance work to the previous work which forms its basis. In every case the inherent errors or weakness of the previous must enter the new work. Hence great care must be exercised in building upon those parts of previous systems that have a strong basis.

3. PROGRESS OF THE ADJUSTMENTS

The adjustment of the Precise Level Net of the Geodetic Survey of Canada has been enlarged to include the precise level work of the Topographical Surveys. To show the effects of new data and the influence of varying data a differential adjustment has been pursued which may be briefly enunciated as follows. Using the tidal stations of the Naval Service Department at Father Point, Yarmouth and Halifax, all the level net of Canada, even to the Pacific Coast, has been given an adjustment based on them. This adjustment is known as the Atlantic Datum Adjustment. The effect of the tidal stations at Vancouver and Prince Rupert will be of an additive nature to the Atlantic Datum Adjustment and when such effect is determined we will have the Pacific Datum Adjustment. The next step is the introduction of a number of American circuits along the border adjoining Western Canada. This will bring into our adjustment American levelling (previously unadjusted) as far south as points held by the United States Coast and Geodetic Survey as standards. These points to be held are Stephen and Crookston in Minnesota, Huntley and Butte in Montana, Pasco and Seattle in Washington.

Thus a final adjustment will be obtained which will show the effect of the inclusion of the Pacific tidal stations and of the American points. And it is to be noted that the total additive effect gives an adjustment which is the same as if all the observations had been adjusted in toto.

The prairie section of the level net is shown on page 23.

The triangulation adjustments of the Maritime Provinces have been extended and will now include all of Cape Breton island. To extend this so as to give a basis for Newfoundland is a natural hope. In Western Ontario the city of Toronto work has been finished. The main triangulation net of Western Ontario, embracing two bases and two Laplace points, is practically completed.

4. DETERMINATION OF THE PRECISION OR PROBABLE ACCURACY OF SIDES AND OTHER EXTERNAL PARTS OF THE TRIANGULATION OR OF A LEVEL NET AS ADVISORY FOR NEW FIELD WORK

The very fact that the ordinary field errors of any one engineer are local, and that such local errors must be combined with the errors of other engineers, shows that some cognizance must be taken of how such errors combine. This brings about the subject of accumulative error.

As no errors are exactly known, the combination of such errors to form accumulative error, can only be found by the discussion of probability.

Accumulative error throughout different engineers' work will show itself in the necessity for the location of a base or a Laplace point; the former to check the scale, the latter to control the deviation in geodetic azimuth. But it is to be carefully noted that it cannot be prognosticated when such base or Laplace point should be inserted


CITY OF LONDON
ONTARIO
PROGRESS MAP
THE SURVEY OF LONDON

before an analysis of the accumulative accuracy of the triangulation or level net is performed. Too often there is a tendency to test field work only by an analysis of the local work of an engineer and not by an analysis of the whole work of all the engineers.

To discuss such analysis of error, a differential adjustment of errors has been evolved and it is believed it will be far reaching in its analysis and detection of errors. This theory has been applied with great success to some of our work, particularly in British Columbia.

The adjustment of the precise level net, embracing the levels of the Geodetic Survey and of the Topographical Survey will be given this differential adjustment.

5. DETERMINATION OF FIELD DATA AS SUITABLE FOR ENGINEERS, SURVEYORS AND THE GENERAL PUBLIC

The determination of field data is always of two kinds, preliminary and final. Preliminary data is necessary in order to meet the demands of engineers for immediate results and engineers are always advised as to the degree of accuracy of the work. The inclusion of new data, new observations, new controls, naturally will add refinement to the old data, but such transformation of preliminary to final must of a consequence take a number of years. But unless such new material is added and adjusted with the old the errors of the old will be magnified with the distance, and distortion will increase. Preliminary adjustments that are built up on other preliminary adjustments require to be combined in one adjustment.

CITY MAPPING DIVISION

DOUGLAS H. NELLES, *Supervisor of Topography.*

1. *The Geodetic Survey of London, Ont.*—The survey of London was resumed on May 16 by Mr. F. P. Steers, engineer in charge of the survey, who proceeded to select and mark traverse stations, so that everything would be ready for the observing and chainage parties to start the first week in June. As Mr. Roberts was delayed in Ottawa for about three weeks the writer took over his party until he reported for field duty.

The scope of the season's work planned was to finish up as much as possible of the traverse and secondary level net within the city limits and to measure up enough details to complete four map sheets; the numbers being 66, 67, 85 and 86. The progress map of the work completed to date is shown opposite this page.

2. *Traverse Observing or Angle Measurement.*—These parties, of which there were two, were composed of an instrumentman and two picketmen or targetmen. The instrument used was a six and a quarter-inch theodolite reading to ten seconds. As the length of sight in a city is short, between 200 and 700 feet, a special target was designed as illustrated in fig. 1 and fig. 2. Fig. 1 shows the target face composed of a brass shield on which is painted a white line one eighth of an inch wide on a black ground. At the bottom of the shield is a projecting steel pin placed so as to line up with the white line and of such a diameter as to fit snugly into the $\frac{3}{8}$-inch hole in the copper bolt of the traverse station. The white line is made vertical over the traverse point by means of the cross levels adjusted by levelling screws as shown in fig. 2. Clamps A and B in fig. 1 are for the insertion of a small steel rod for sighting on when a rise in the sidewalk makes the target invisible. When a rise is great enough to make this two-foot rod invisible, a half-inch steel picket is plumbed over the point and held by guy lines to stakes.

Each traverse station was marked by a half-inch copper bolt one and one-half inches long with an $\frac{3}{8}$-inch hole drilled in the top, cemented in the concrete sidewalk. In places where there were no sidewalks, iron posts were used, made from an inch-pipe three feet long, capped on the top and pointed at bottom and driven flush with the ground surface.

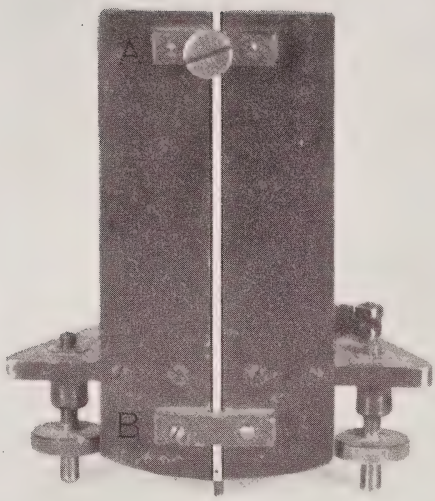


Fig.1

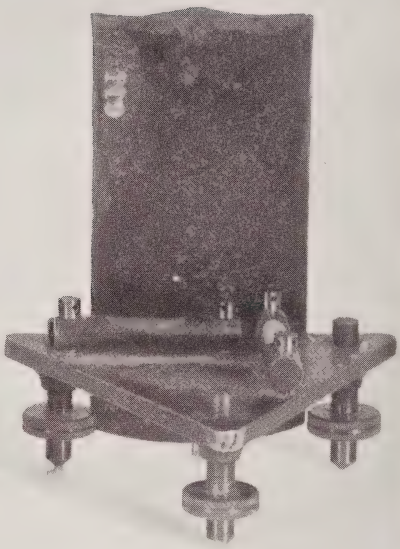


Fig.2

Fig.3

Fig.4
Tape Setter

Fig.5
Spring Balance

The observing program at each station was to set the instrument at zero in the direct position, point on the back station, swing round to the right and point on the forward station. This measurement of the angle was repeated three times. The instrument was then put in the reversed position, pointed on the forward station and swung round to the right and pointed on the back station, this measurement was also repeated three times and the mean of the six measurements of the angle was taken.

One thing that delays progress more than anything else in precise city traverse work is trying to set the instrument accurately over a point when a wind keeps the plumb bob swinging. To enable an instrument to be set up quickly and accurately in a high wind, a simple apparatus was designed as illustrated in fig. 3. It consists of a steel tube attached to the projection of the vertical axis of the theodolite to which the plumb bob is attached and swung from a ball and socket joint. A solid stub steel bar slides up and down the inside of the tube, having its lower end brought to a point. Attached to the tube is a level whose graduations are equal to 90 seconds. In setting up the theodolite the point of the bar is inserted into the hole in the copper bolt and the instrument centred over the point by making the apparatus perpendicular by means of the attached level. When this has been done and the instrument is levelled, it is then exactly centred over the point.

3. *Measurement of Traverse Lines.*—The measurement of traverse lines was made with a 200-foot steel tape, graduated to feet and hundredths, readings being estimated to thousandths. The rear end of the tape was held in position by a specially designed instrument called a "tape setter" as illustrated in fig. 4. The tape is attached to the setter at "A" and placed with its zero approximately over the station centre. A tension of 12 kilograms was applied to the forward end of the tape by a spring balance as illustrated in fig. 5. The tape zero was then made to coincide with the centre of

the station mark by means of screw "B," fig. 4. Screw "B" has a swivel attached to its end to which is attached a small section of steel tape, which is turned at right angles by means of a roller and passes out through the front of the setter, having a hook at the outer end to which to attach the measuring tape. The tape being stretched, the 200-foot graduation was transferred to the pavement by a knife-edge mark. Two thermometers were attached near each end of the tape and readings taken at each tape length. A chalk mark was put on the top and the side of the pavement opposite the end of each tape length and at every change of grade, the distance of which was noted. Levels were then run over the traverse establishing the elevations of the traverse stations, tape end marks and changes of grade.

Each line was given two measurements, one forward and one backward and after making a rough correction for temperature, the two measurements were required to agree to within one in fifty-thousand, or to be remeasured until such an agreement was reached.

4. *Detail Measurements.* On one corner of every street intersection, a copper bolt was placed, marking a traverse station. From any one of these bolts it is possible to see four other bolts at the street corners to the north, south, east and west. The officer in charge of a detail party, first has the distances measured to the edges of the sidewalks and curbs on all four corners, with reference to the traverse stations and lines between traverse stations.

A 200-foot steel tape is next stretched along the inner edge of the concrete sidewalk, the zero of the measurement being at the copper bolt or on a line between bolts. In tying in buildings, four measurements were taken, two to each of the two front corners, from two places on the tape so as to form a well proportioned triangle. The party first located the fronts of buildings in this manner and all the details of the street, such as hydrants, catch basins, telegraph poles, etc., then the buildings were measured up and all the details of the interior of the block, such as outhouses, trees, fences, etc. Measurements were taken as far as possible so as to have a check upon their correctness, for instance, line fences at the back of lots were measured from both streets, or if there was an alleyway its width was measured. Secondary measurements were made with a metallic tape.

5. *Thirtyone Mile Lake Watershed Map.* Mr. B. J. Woodruff, Junior Geodetic Engineer, has been engaged for part of his time in plotting this map by the stereophotogrammetric method. This being the first map to be plotted in Canada by this method. The scale is 1/10,000 and the area being plotted comprises 100 square miles, and is covered by 49 stereophotogrammetric stations. In the southern part of the work the stations were put in a little more closely; this was necessary to cover the territory and made plotting slower at first.

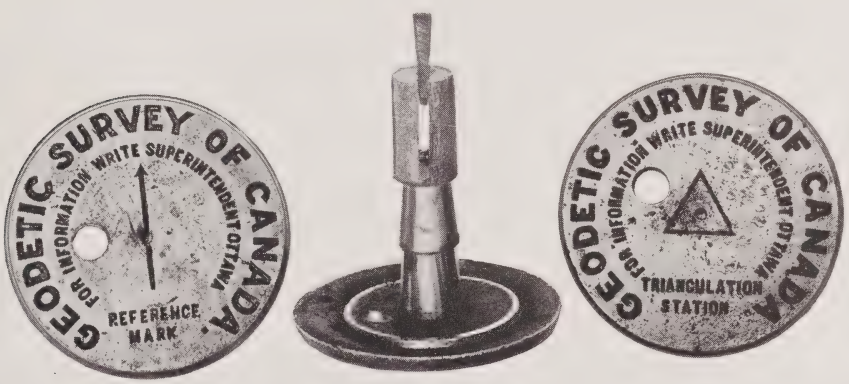
Atmospheric and other conditions in this district made plotting at a distance of over 2,500 metres somewhat unreliable. As the country is covered with dense forest, the elevations obtained are more or less approximate, except where a bare hill top is the point. The method itself gives accurate results where the conditions are at all favourable. Before using elevations obtained from a pair of plates, checks for the accuracy of the results were made upon a triangulation station or the water level of a lake. For instance, a check on station Devil from station No. 133, a distance of 4,392 metres or 2·7 miles, agreed to within four feet. On Blake from Deer, a distance of 4,755 metres or 2·95 miles, the agreement was within two feet. In practice, elevations were read to the nearest five feet and if a known elevation did not check to within that margin, the source of error was discovered and rectified.

Fifty square miles of map has been completed, plotted from 79 bases, based upon 24 stations, the contours being located from 1,971 plotted points. This gives 39·4 points to the square mile and it is a coincidence that for the first hundred square miles of this watershed, plotted by different topographers, by the method of photo-intersections, the number of points per square mile was 39·3.

The Application of Aerial Photographs to Map Making. During the year investigations have been carried on in regard to the best methods of transfering the information contained in aerial photographs to a map and also in regard to what errors were contained in a mosaic made by assembling aerial photographs and the method of calculating these errors. The results of these investigations will be embodied in a special publication entitled "The Application of Aerial Photographs to Map Making."

The Aerophotoautograph. A confidential report has already been made on this instrument, invented and designed by the writer, for the purpose of plotting the geographical positions and obtaining the mean sea-level elevations of objects upon the earth's surface, from aerial photos, mechanically, without any calculations, except for the ground control. The machine can be set at the elevation of a certain contour and the contour drawn out directly on the map. The mechanical detail drawings are expected to be in practical shape by the first of April, 1923, and it is hoped to have a machine made in Canada for experimental investigation.

Field Operations of 1921, Survey of London, Ont. The report of Mr. F. P. Steers, Geodetic Engineer in Charge, is as follows: Field operations were started in London on May 15 and three weeks were spent in selecting and marking courses for chained traverse through the city. Five hundred and ninety-three stations were selected and



TRIANGULATION STATION AND REFERENCE MARK TABLETS

These tablets are leaded into solid rock or are set in concrete monuments to mark, and reference triangulation stations. The wedge spreads the embedded end of the shank when the tablet is driven down thus adding to its solidity. The hole in the top of the tablet allows the melted lead to enter and fill the space around the shank, to hold it in its place.

marked by a copper bolt, 1½ inches long by ½ inch in diameter, cemented into the concrete walk. Seventy stations were selected on unpaved streets and marked by an iron pipe 3 feet by 1 inch, pointed at the bottom and capped by an ordinary pipe cap. These pipes were driven in flush with the ground and referenced by at least three measurements to the nearest permanent, natural and artificial features.

On June 8th the main party was formed and camp was established at the northwest corner of the city. The party consisted of the Engineer in Charge, five assistant engineers classed as "Instrumentmen", 12 rodmen, chainmen and recorders and a cook. From June 8th to September 18th, when the city of London's appropriation for the survey was exhausted, the following amount of work was accomplished as shown on the progress map as compared with last year's map.

Traverses totalling 62·5 miles were double chained, with a 200-foot steel tape, temperature, tension, grade and catenaries being measured and recorded. Sixty-one miles of levels was run and the elevations of 655 traverse stations and 11 permanent benchmarks were determined. Spot levels were taken every 100 feet along traverse lines and at every change in grade. Six hundred and fifty-five traverse stations were occupied with a 6¼-inch Berger repeating transit and on an average 2 angles per station were measured by the repetition method, employing three repetitions. The topographic details of 83 city blocks, comprising 566·6 acres, were surveyed, by means of chained offsets from traverse lines.

The area in which the topographic details were surveyed includes the greater portion of the congested business section of the city, as well as three railway stations and freight yards. Consequently, to avoid the heavy traffic in this area, the major part of the work had to be done between daybreak and 9 o'clock in the morning, after which hour parties working in this section had to be moved to a quieter section to finish their day's work. Camp was struck on September 18th, and the party returned to Ottawa.

MOST WESTERLY LINK OF THE GENERAL SCHEME OF PRIMARY TRIANGULATION ACROSS THE CONTINENT

H. F. J. Lambart submits the following report of the British Columbia Reconnaissance operations, being the initial step in the primary system of triangulation from the coast eastward across the province.

Commencement of the British Columbia Operations

Primary triangulation reconnaissance across British Columbia from west to east was under consideration in the spring of 1920, but due to the Ottawa Aerial Photo-topographical experiments which were carried out in that year this work was postponed to the following year.

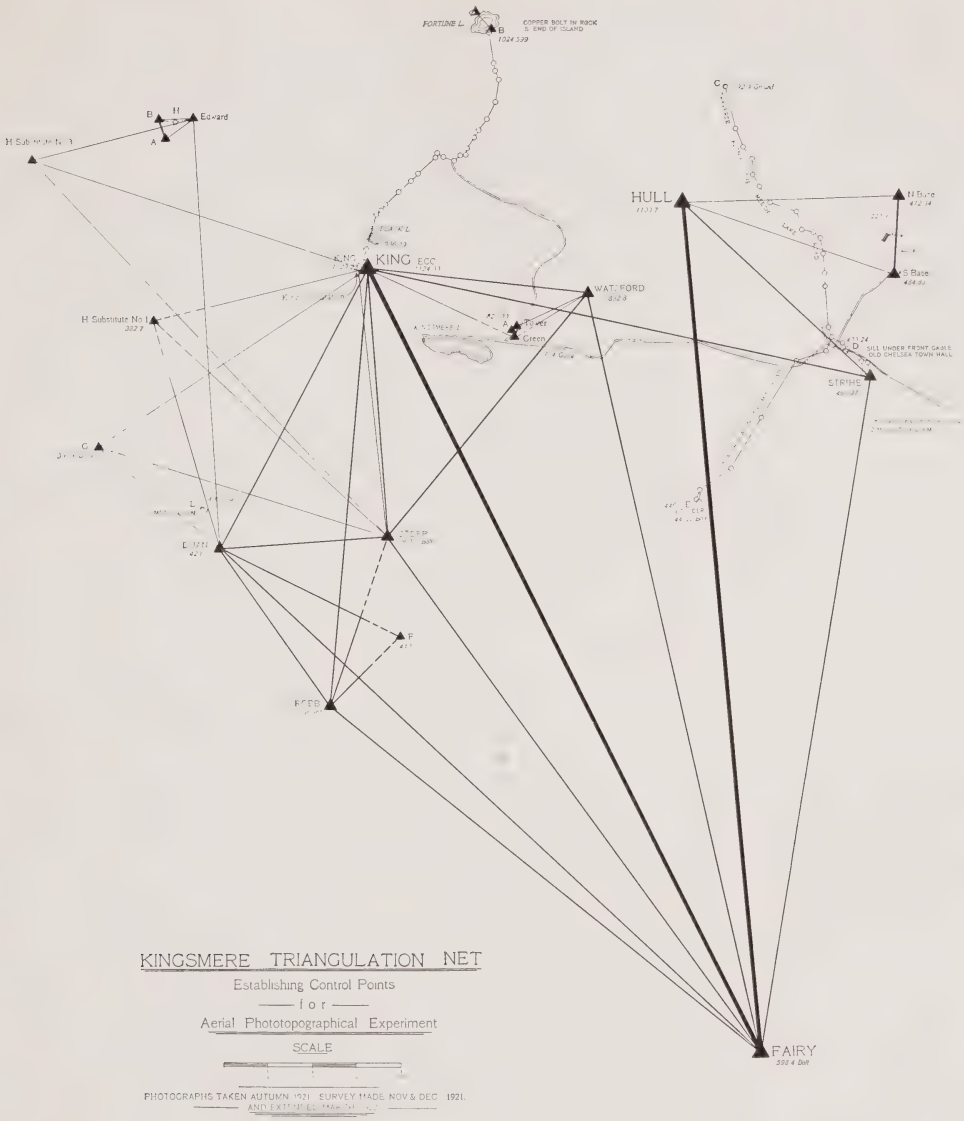
On reaching the coast on the 29th of May, 1921, the Provincial Land Office at Victoria was visited, and in conversation with Mr. Umbach, the Surveyor General, useful connection possible with the prairies, connecting there with the primary system was by way of the railway belt. Due to the facilities of transportation and the numbers of surveys along the line of the belt, this was considered the most useful connection possible with the prairies, connecting there with the primary scheme working westward along the International Boundary line.

The commencement of the work was forthwith undertaken and with this object in view the old primary triangulation stations of Bruce and Constitution (the latter on the American side of the border, on Orcas island) of the Coastwise system of Primary Triangulation, were visited.

A good expansion from these two points and Gardner, on Bowen island (at the entrance of Burrard inlet) was effected eastward up the valley of the Fraser river to two points, Vedder, near Sumas lake, and Alouette, on the east side of Pitt Arm.

Old Stations Visited

As mentioned above, the three primary stations of Constitution, Bruce and Gardner, constitute the starting points of the survey eastward, and the primary lines connecting these points serve as the Western Base lines of the eastbound system. These points connect eventually with the American primary systems from the south, placing the whole on the North American Datum in the final adjustment.



First Application of the Aeroplane to Primary Triangulation Reconnaissance.

For the first time, so far as known, primary triangulation reconnaissance has been conducted with the aid of the flying machine.

Co-operation with the Air Board of Canada

In co-operation with the Air Station Superintendent, the late Major C. MacLaurin, at Point Gray, Vancouver, the use of the Flying Boat known as "HS2L," and another much larger craft, known as the "F3," the triangulation system was projected as far as the commencement of the Fraser Canyon near Hope.

From the air all this country was examined and the figures of the scheme largely determined.

The flying boat was brought into most effective use in a two-fold sense; first and most valued of all, as a means by which the country could be carefully scrutinized, and secondly, as a means of transportation of personel, equipment and camp gear to and from the water landing places nearest to the stations determined.

During the first part of the summer's operations and also toward the last when the flying base was changed to Kamloops, the survey was very fortunate in its selection of stations, which in many instances were quite close to lakes, into which the plane could safely land, and the party go into camp from where eventually the station was climbed.

Landing facilities around Kamloops permitted of the same procedure and it is interesting to note, as a demonstration of the great value these machines have been to the survey during the summer, that in one single flight lasting but a few hours, the complete system as shown mapped out about Kamloops, was completed and needed little or no correction when the stations that were selected came to be occupied.

It should be explained that on landing, to get to shore, either a canvas collapsible boat which was carried was used or when the weather and shore line permitted, the party stepped from the nose of the machine direct to land.

In the complete summer's operations of 250 miles from Vancouver island to the Okanagan, the middle part only of the net, that which lay to the east of the canyon of the Fraser, had to be done by hard toil in the old way without assistance from the air.

Dimensions, Effective Lift and Performance of Flying Boat, HS2L (Information supplied by Air Board)

Span, 74 feet 2 inches
Height, 14 feet 7¼ inches
Length, 38 feet 5 15/16 inches
Weight, without load, fuel or oil, 4,140 pounds
Seating capacity, 5
Type of Engine, 12 cylinder Liberty, Pusher, H.P. 385
Load not to exceed 1,760 pounds

HS2L Flying boat G-CYEA made an altitude of 8,000 feet in 54 minutes, developing a ground speed of 75 miles per hour, and consumed in a run of one hour and seven minutes, 25 Imperial gallons of gasoline and one gallon of oil, with the following load:—

Petrol, 108 Imperial gallons.....	756	pounds
Crew, 3 at 180 pounds.....	540	"
Anchors, 1 at 20 pounds, 1 at 10 pounds....	30	"
Collapsible boat.....	15	"
Camera fittings.....	40	"
Coats, rope, etc.....	20	"
	1,401	
Leaving still a possible loading of;.....	359	"
a corresponding slower and lower possible lift.		
	1,760	"

Dimensions, Effective Lift and Performance of Flying Boat F3:

Machine, F. 3. (Boat Seaplane).
No. of Seats (Crew and passengers). Variable 4 to 8.
Engines, 2 Rolls-Royce Eagle VIII, 360 horse-power each.
Speed, (miles per hour).
At 5,000 ft., Max. 86, Cruising 65, Minimum 47.
Climb, to 2,000 feet, 5.6 mins., 6,500 feet, 24 mins.
Ceiling, 10,000 feet.
Air endurance, 10 hours at 5,000 feet.
Air miles per gallon of gas (at 5,000 feet cruising speed)—2.22.

Weight.	Lbs.	
Gross	13,281	
Empty (with water)	7,958	
Fuel and Oil	3,160	Variable according to whether *Range* or *Load* is the important Factor.
Useful Load	1,443	
Crew (4)	720	

Capacity.	Gals. (Imperial measure.)
Fuel	405
Oil	25

Consumption, (Gal. per hour at cruising speed).	
Fuel	35
Oil	2

Dimensions		
Lifting Surface	1,430	Sq. Ft.
Span	102	Ft. 0 Inches
Length	49	" 6 "
Height	19	" 8 "

The F3 Boat, as will be seen from the schedule of the summer's flight, was only used on one occasion, while all the rest of the fifteen flights were made in the HS2L.

Transportation of Camp Equipment in HS2L.

It is seen that the capacity of this machine is sufficient to carry quite a complete camp equipment in addition to all the other accessories, and a crew of three.

From experience gained on the first flight from Vancouver to Alouette lake and from there to Cultus lake and back to Vancouver, all deficiencies were corrected before resuming work for the remainder of the season.

Space being very limited a silk tent as compact as possible and three wicker baskets made to fit convenient recesses in the machine carried the major portion of our outfit. These light preparations proved highly satisfactory and were used throughout the season.

Its Utility Depending Upon the Presence of Lakes and Rivers.

The British Columbia Coast and inland for many miles is adaptable only for the water machine, the capacity to land depending wholly upon the presence of sufficient water area to allow the machine to get off the water after it has landed and sufficient room to gain the necessary height to clear all surrounding elevated ground. Generally speaking a clear run of three quarters of a mile is required. The country to the east and north of the canyon of the Fraser was largely without the presence of water large enough for landing purposes until the Nicola Lake region is reached, where the use of the machines was again resumed, operating from a temporary base established by the Air Board at Kamloops.

With the exception of the stations Sutter, Roy, Livingston and Pennask, all the stations were practically determined from information gained of the character of the country as it was flown over, with a map spread out in front of the engineer in the cockpit of the machine.

Costs and Comparative Costs, Compared with the Old Methods

This is a very difficult question to settle satisfactorily; the saving of time and energy is very great and the opportunity constantly afforded of an unobstructed view of the country from any height and position desired is an advantage that can hardly be compared to any of the old ground methods of determining the location of suitable points for the scheme of triangulation.

To cite two very outstanding examples of last summer I mention that of the location and climbing of the point Barr. This point was sighted and fixed in position from Vedder and Alouette, and to reach it by any ordinary means meant a train journey from Vancouver to Ruby Creek of 80 miles, thence across the Fraser with equipment in canoe and finally to Jones lake by a steep pack trail of seven miles ascending to an elevation of over 2,000 feet above the Fraser river at that point.

This same journey was made from Vancouver to Jones lake by air with equipment in less than two hours without the expenditure of an ounce of energy on the part of the engineer.

The ability to reach the foot of an arduous ascent in a fresh state is by no means a feature to be lightly overlooked by any one who has had the experience of a strenuous four or five thousand foot climb ahead of him.

The other case in point was that at Kamloops where nothing could be gained by an inspection of the available maps of the country, and which to obtain by the ordinary method of a series of skirmishes about the country to the nearest and highest available points, would have perhaps represented a week's labour. All was accomplished in an afternoon's flight during which it was possible to lay out the complete scheme of figures that are to be seen in the sketch of the triangulation, as subsequently laid out.

Comparative costs to any degree of reliability cannot be obtained, as the two methods are so absolutely different and no tangible value in dollars and cents can be placed on the immense value it is to gain a panoramic view of any section of the country at will.

The time it would have taken to complete this work under ordinary methods would have been three years; it was accomplished by means of an aeroplane in one short summer; the total cost to the Survey being $4,700 and to the Air Board $2,300, a total of $7,000. A rough estimate of the saving being $12,000.

Concluding Remarks Regarding Use of Aircraft

In conclusion it seems reasonable to suppose that the future of triangulation reconnaissance through a difficult mountainous country can ill afford to do without the services of an aeroplane; in fact, it is a pretty safe prediction to say that no such survey would be attempted without their use.

The machines in use in Canada to-day are relics of the war and, hence, are a makeshift when adapted to any form of civilian flying.

The Air Board hope to put into commission a machine designed specially for patrol and photographic work which will infinitely increase the efficiency over those used at present.

Colonel Steadman has kindly given me the specification and performance of this machine as follows:—

A biplane with 500 H.P. Napier engine.

Weight without fuel	4,880 pounds
Seating capacity	5
Cruising radius	10 hours.
Maximum full load	1,950 pounds.
Load, persons, etc	750 "
Total maximum load	2,700 "
Ceiling at full load	15,000 feet.
Climbing with full load	700 feet per minute.
Maximum speed	100 miles per hour.
Cruising speed	95 " " "

All this means that the small and the high level lakes, near the ceilings of the old machines of last year, which could not be used, will now be made accessible and on account of the high ceiling, country which heretofore would be considered unsafe will now be traversed in comparative safety at a high altitude and in the event of engine failure, would have an infinitely wider range of country in which to find water.

General Remarks on the Reconnaissance Through the Coast Range and Character of the Country

On the coast the difficulty of some of the ascents through the brush and fallen timber tangled up with the "devil's club," was indescribable, and should never be attempted where a station is being established without first cutting a trail.

The conditions vary greatly in the same locality being affected by the exposures, altitude and proximity of other high mountains which catch and condense the moisture laden clouds which come in from the coast and produce local conditions of rainfall, differing widely from others which may be only a short distance removed.

The summit of the Cascade range which parallels the Canyon of the Fraser on the west and crosses the Fraser valley at its pronounced right angle bend north at Hope, is the dividing line between the wet and dry belts. Standing on station Fan (one of the two stations established on the summit of the range), and turning westward—towards the coast—the whole sweep of mountainous country is covered with dense timber and verdure; above the tree line the perpetual snows. Turning eastward —inland—the pronounced change comes with no little surprise; there we have the very rugged mountain ranges and deep furrowed valleys but not a suspicion of snow to be seen anywhere on the bare rocky tops and as for the lower lying country, in comparison with what has just been seen to the westward, they appear as burnt wastes of country; the contrast is most remarkable.

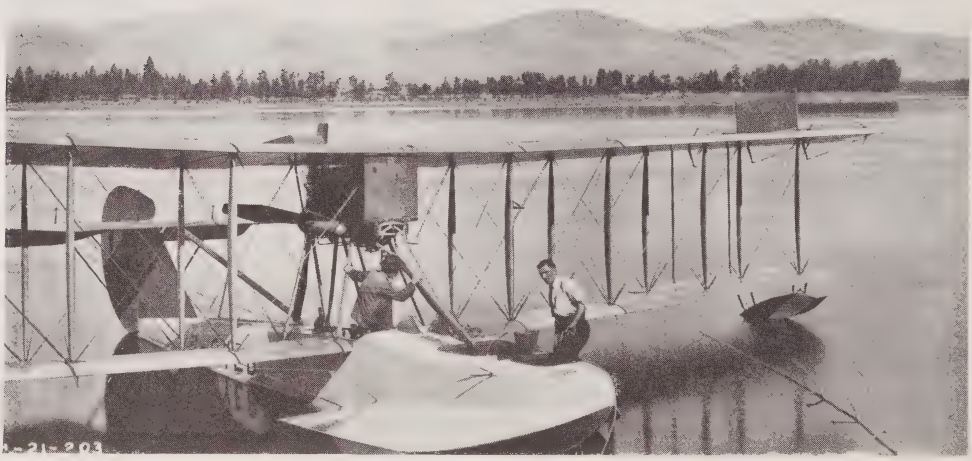
The conditions for carrying on triangulation west of the Cascade will prove much more difficult than east of this range. Constant fog and rain has been observed to the westward while standing in bright sunlight on an elevated point near Mount Tulameen.

The contrast as all British Columbia knows between Kamloops and the coast is as marked as day and night and for our work the interior of British Columbia is vastly superior.

Triangulation Station Fan. Point on the crest of the Cascade Range.

From what has been said it is not difficult to see why the Alpine Club of Canada have left untouched the magnificent mountains of the coast and seek the much better climatic conditions prevailing in the Selkirks.

The season's operations were very short; date of leaving Ottawa, May 26 and returning September 19.



Reconnaissance in British Columbia. Base of operations for Kamloops, B.C.

Water front at Kamloops, B.C. Air Station Base.

Summary of Flights

Altogether some 15 flights were made from June 9th to September 1st. The total hours of flying was 28·24; the total mileage 2,026, with an average speed of 71 miles per hour. The altitude of the flights was from approximately 2,500 to 9,300 feet. The amount of information obtained and the experience gained in the methods of procedure were remarkable.

The total cost of operations to the Air Board at $82 per hour, was $2,332.

Hydrographic Signal, Gulf of St. Lawrence. Triangulation Station being established and marked at the same point.

PROGRESS ON THE PACIFIC COAST

H. B. Kihl

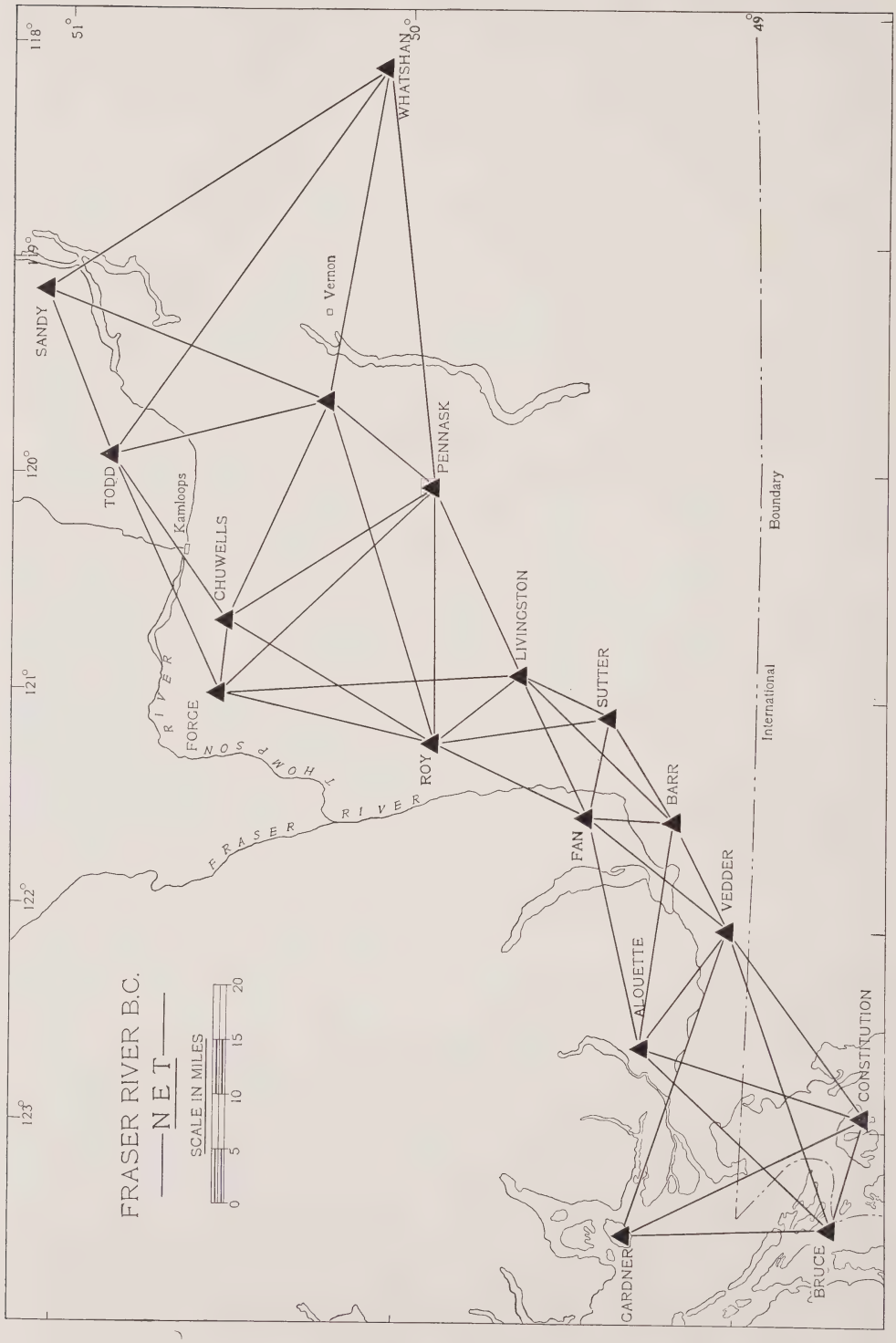
On April 23 the writer proceeded to Vancouver, arriving there April 28. A few days were spent in engaging men, buying supplies and having the Geodetic Survey Launch *Metra* overhauled and repaired. Twenty-three men were engaged, and of these twenty were returned soldiers.

The majority of the party were sent to the base camp at Fort Rupert on one of the Union Steamship Company's boats on May 5, and the remainder were taken there on the *Metra*, which left Vancouver two days later and arrived at Rupert on the 10th. Two days were occupied in organizing and equipping the parties, and on May 13 most of the men were distributed to the various stations.

The party was divided into two observing parties, one station preparation party, five lightkeeping parties, the crew on the *Metra* and a storeman.

The first part of the season was spent in re-measuring a number of directions in the vicinity of the Fort Rupert base line, in order to improve the accuracy of the triangulation in that section. Eight stations were re-occupied, and the additional work produced results well within the limit of required accuracy.

The triangulation was then extended across the Queen Charlotte Sound. This part of the season's work was very slow on account of fog, which for long periods made


FRASER RIVER B.C.
NET
SCALE IN MILES
0 5 10 15 20
WHATSHAN
SANDY
Vernon
TODD
Kamloops
CHUWELLS
PENNASK
LIVINGSTON
SUTTER
FORCE
ROY
FAN
BARR
VEDDER
ALOUETTE
CONSTITUTION
CARDNER
BRUCE
FRASER RIVER
NOSDAWOHI RIVER
International Boundary
118°
51°
119°
120°
121°
122°
123°
49°

observing impossible and navigation difficult. About the middle of September this work was finished and the operations extended north along the Coast.

Difficulties were encountered in locating a station on Goose island as only part of this island could be seen from Calvert station. In this case the line of sight passes through a gap in a high mountain ridge on Calvert island. After some delay a suitable station was established and observations were made on it from Calvert and King.

Messrs. J. A. H. Henderson and G. R. Martin were in charge of the observing parties and Mr. H. N. McLellan had charge of the preparation of the stations. Each observer was assisted by a recorder, a cook and a lightkeeper.

The lightkeepers worked in pairs. Each party had two lights, which were placed one above the other over the station mark and pointed to the stations occupied by the engineers.

The transportation of men and outfits from one station to another was made by the launch *Metra,* which ran approximately 5,000 miles without a single mishap. The crew on the *Metra* were the chief of the party, an engineer and a cook.

The season's work concluded about the end of October. The outfit was stored at Fort Rupert and the *Metra* laid up at the Vancouver Ship Yards, Vancouver. The engine was overhauled by the engineer and the bottom of the boat cleaned of barnacles and copper-painted by the Vancouver Ship Yard Company.

During the season eleven stations were occupied and completed. The most northerly station occupied by the lightkeepers is located on Roscoe inlet in Latitude about 52° 24′.

PROGRESS ON THE 49TH PARALLEL FROM THE 109TH MERIDIAN TO THE LAKE OF THE WOODS

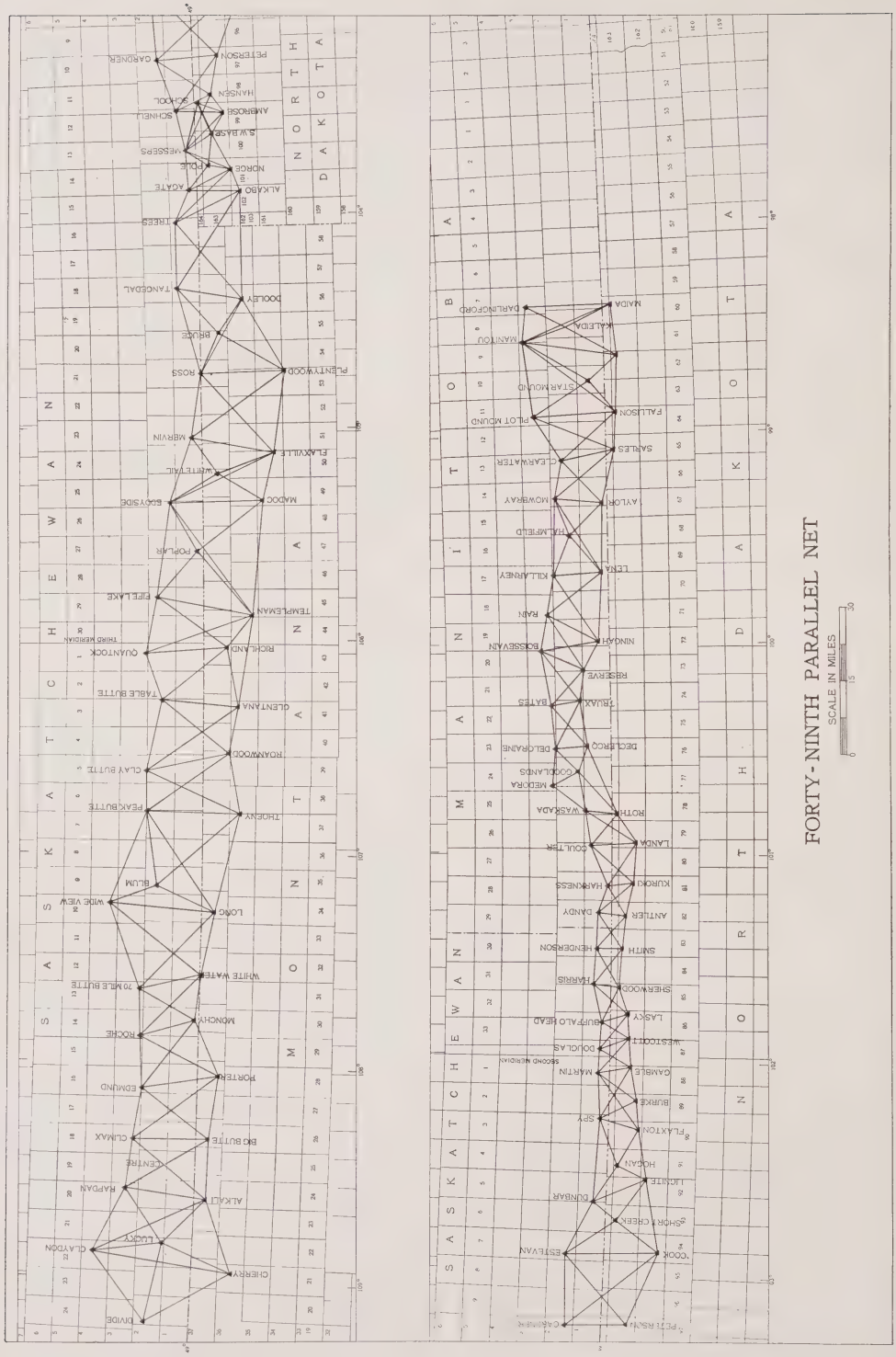
W. M. Dennis

This work was carried out as the result of an agreement with the United States Coast and Geodetic Survey, that a chain of primary triangulation along the International Boundary, to connect the primary triangulation on the Lake of the Woods with that on the Pacific Coast, would be of great value to both countries. By dividing the chain at the 109th meridian, and each country carrying out one part of the scheme, it was thought the cost would be about evenly divided. The advantage of such an agreement is chiefly economic, thus Canada obtains primary control along her southern border from Lake of the Woods to the Pacific Ocean, at about one-half of the cost of the total work. The North American Datum will be available at any point on this border from Lake Superior to the Pacific Ocean for triangulation, to supply control where required throughout the settled west.

Through the courtesy of Col. Jones, this survey was given the choice of the section, east or west of the 109th meridian, and the section from the 109th meridian to the Lake of the Woods having been decided on, the writer received instructions to carry out this work.

The North American Datum had been brought up to the International Boundary at the 104th meridian by the United States Coast and Geodetic Survey, so it was decided to begin reconnaissance from this control, working both east and west therefrom. After the necessary preparations had been made, work was begun here on May 17.

It was found difficult here in tieing in with this work to obtain a strong connection, and extend the triangulation east and west along the boundary. The point "Messer" was located and tied to School, Ambrose, South West Base and Norge in such a way that the eastern work could be built on the line, "Messer—Ambrose", and the western work on the line, Messer—South West Base. The party was then divided, Mr. W. H. MacTavish, with one assistant, working east, the writer and one assistant, westward.


FORTY-NINTH PARALLEL NET
SCALE IN MILES
0
15
30
NORTH DAKOTA
SASKATCHEWAN
ALBERTA
MONTANA
SECOND MERIDIAN
THIRD MERIDIAN
PETERSON
GARDNER
HANSEN
SCHOOL
SCHNELL
ANDROSE
S. WASSE
WESSEPS
NORGE
FOLDE
AGATE
ALCADO
TREES
TANGEDAL
DOOLEY
BRUCE
ROSS
PLENTYWOOD
MERVIN
FLAXVILLE
WHITEVALE
BOOYSIDE
MADOC
POPLAR
PIPE LAKE
TEMPLEMAN
QUANTOCK
ROCHLAND
TABLE BUTTE
CLENTANA
ROAMWOOD
CLAY BUTTE
PEAK BUTTE
THOENIX
BLUM
WIDE VIEW
LONG
WHITE WATER
70 MILE BUTTE
MONCHY
ROCHE
EDMUND
MORTEN
BIG BUTTE
CLIMAX
CENTRE
RAFDAN
ALKALI
LUCKY
CLAYDON
CHERRY
DIVIDE
NADA
KALEIDA
MANITOU
DARLINGFORD
STARMOUND
PILOT MOUND
FALLISON
SARLES
CLEARWATER
AYLMER
HALMFIELD
LENA
KILLARNEY
RAIN
NINGAH
BOISSEVAIN
RESERVE
BATES
DELORAINE
DECLARO
COOLLANDS
NEDORA
WASRADA
ROTH
LANDA
COULTER
HARKNESS
KIRKHOLD
ANTLER
DANDY
SMITH
HENDERSON
HARRIS
SHERWOOD
LASKY
BUFFALO HEAD
WESTCOTT
DOUGLAS
SECOND MERIDIAN
MARTIN
OAKBLEE
BURKE
SPY
FLAXTON
HOGAN
LOVLITE
DUNBAR
CHORKCHEER
COOK
ESTEVAN
PEPPERSKY

On the western section the topography of the country is undulating, making it possible to obtain a greater average length of line than on the eastern section. Throughout this section the average width of triangulation is 18.7 miles. This width was obtained without committing the survey to large expenditures for towers, only three towers being necessary for forty-eight stations.

When nearing the western end of the Canadian division of the triangulation scheme, the writer, through the office at Ottawa and the office of the United States Coast and Geodetic Survey, was able to get in touch with Mr. C. L. Garner, of the United States Coast and Geodetic Survey, who had instructions to carry out the reconnaissance on the adjacent section. A meeting was arranged at Turner, Montana, and the connection between the two divisions was located jointly. Thus good continuity and strength of figures were obtained without the use of extra stations, which are generally required when connecting with triangulation previously located.

Data—Western Section:

Number of stations	48
Number of towers	3
Distance in miles	246
Area in square miles	4,600
Average width in miles	18·7

The topography of the section between the 109th meridian and the Lake of the Woods changes at about the 103rd meridian, from undulating to more level prairie. While the West is treeless, bluffs or small patches of poplar are scattered regularly over the section east of the 103rd meridian. These conditions make an almost constant use of the portable tower necessary and the average length of lines is less and progress necessarily slower. Due to this condition Mr. MacTavish found the reconnaissance on parts of this section very difficult. The figures were gradually enlarged to a width of 20 miles at the 103rd meridian. East of this point it was found this width could not be maintained and at the 102nd meridian the figures had contracted to an average width of about 7·5 miles. This width was maintained to about the 99th meridian. At the end of August the western section of the reconnaissance had been completed and shortly after the writer joined Mr. MacTavish, bringing a second portable tower into play. The width of the triangulation was here easily increased to about 20 miles, the width carried as far as the 7th Range west of the Principal Meridian. It is very doubtful, however, whether this width can be maintained east of the Pembina mountain.

Data—Eastern Section:

Number of stations	54
Number of towers	35
Distance in miles	239
Area in square miles	2,540
Average width in miles	10·6

It will be seen by comparing the data for the east and west sections, that the topography has a big influence on the average width of the triangulation, the number of towers necessary and on the area covered. The narrow scheme has, however, the economic advantage of supplying a control station for every 47 square miles of area covered, while the larger schemes of triangulation may run as low as one station for every 600 square miles. The points which can be cut in from the primary triangulation between the 109th and the 103rd meridians are confined chiefly to the International Boundary Survey, the Dominion Land Survey and the State Land Surveys, as the country is very sparsely settled in this vicinity and there are few marks of a permanent nature available. On the eastern section more of these marks are available and will be utilized.

Summary:

Reconnaissance is completed from the 109th meridian to the Pembina mountain, or within 18 miles of the 98th meridian.

Number of stations	102
Number of towers	39
Average height of towers	37·1
Distance in miles	485
Area covered in square miles	7,140
Average width in miles	14·7

Two slightly different methods of transportation were used on this reconnaissance. On the eastern section, a Reo truck fulfilled the double requirement of carrying the portable tower and supplying a fast means of doing the large amount of running required in reconnaissance work. This outfit was very satisfactory. On the western section, a Ford truck was used in transporting the tower and equipment when necessary while the running referred to was done with a Ford touring car. This system has the advantage of being more pliable, where many lines have to be tested with lights, but the running cost is a little higher.

TRIANGULATION IN WESTERN ONTARIO

A. M. Grant

The two main operations carried on in this district were the extension of the primary triangulation to Lake Huron including a small supplementary figure to connect with Owen Sound, as shown on page 43, and the triangulation of the city of Toronto and surrounding district as shown on pages 45 and 47.

The observing of the primary directions was carried out by the party under the charge of Mr. H. G. Rose, D.L.S. He occupied the primary stations Carrick, Egremont, Bentinck, Elderslie, Elsinore, Holland and St. Vincent. The station Elderslie is not the same one as originally picked, as it was considered advisable to have the last two primary stations along Lake Huron, in positions where they gave a view of the lake from the ground, and were also intervisible. The two stations Elderslie and Elsinore fulfil these two conditions, as both give a good clear view of the lake and they are intervisible without towers.

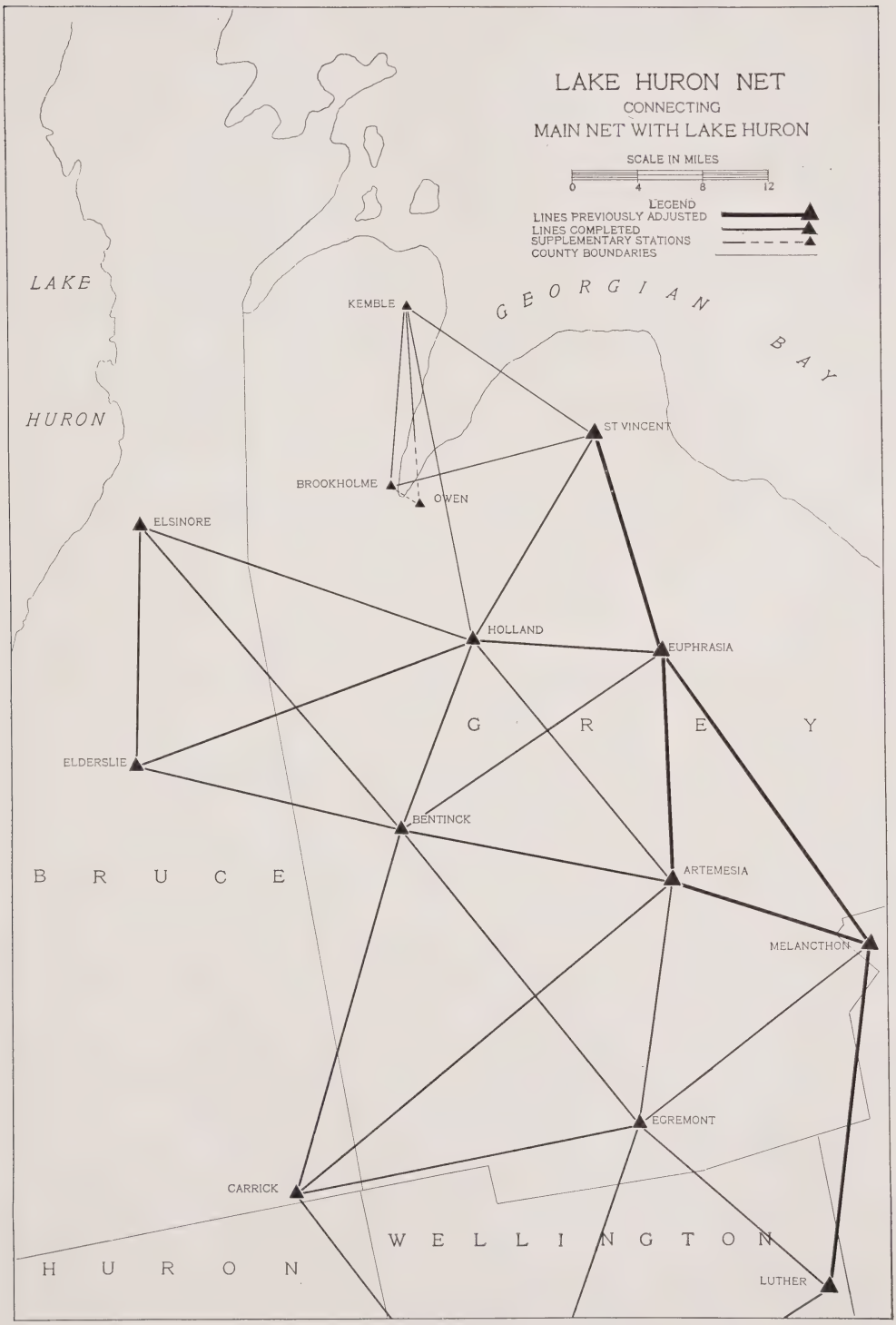
Mr. Rose then put in three supplementary stations in the vicinity of Owen Sound, making a small net which would give good control for any mapping or hydrographic work in that district.

In the observing of these stations Mr. Rose was seriously handicapped on account of the four of the adjoining towers which had to be sighted on, being blown down; the eighty-foot portable tower had to be erected in each case to enable the observations to be made.

Mr. Rose's last work was the completion of a small secondary scheme to connect the primary triangulation with Lake Huron in the vicinity of Goderich. This work is now finished except the building of the monuments. The party disbanded on September 6.

Triangulation of Toronto

The triangulation of Toronto was carried out in the same general way as similar work in Montreal and London, that is by stepping down from the primary triangulation to shorter lines around and in the city. One difference was that Montreal and London asked for points to be accurately established on the streets and sidewalks by triangulation methods, while the city surveyor of Toronto wished to have the stations established on the top of prominent buildings, so that the triangulation scheme could be extended to meet future needs, or any new points required could be located from some two of the stations.


LAKE HURON NET
CONNECTING
MAIN NET WITH LAKE HURON
SCALE IN MILES
0 4 8 12
LEGEND
LINES PREVIOUSLY ADJUSTED
LINES COMPLETED
SUPPLEMENTARY STATIONS
COUNTY BOUNDARIES
LAKE
HURON
GEORGIAN
BAY
KEMBLE
ST VINCENT
BROOKHOLME
OWEN
ELSINORE
HOLLAND
EUPHRASIA
GREY
ELDERSLIE
BENTINCK
BRUCE
ARTEMESIA
MELANCTHON
EGREMONT
CARRICK
WELLINGTON
HURON
LUTHER

Stepping down from the primary net was accomplished by means of one double quadrilateral depending on the three primary stations Uxbridge, King and Scarboro, and establishing two new stations, Richmond Hill and Upper Canada. On the line Upper Canada to Scarboro was then built the triangulation proper of the city. The sketch on page 45 shows the connection with the primary work and the one on page 47 shows the triangulation of the city with regard to the city boundaries.

In the selection of the points on the roofs of buildings especial care had to be taken in regard to the following considerations:—

Stability—About 90 per cent of ordinary roofs are not suitable as triangulation stations on account of being so unstable that the change of the observer's weight when sighting on different points causes an appreciable error in the measured angles. One station, that on the Royal Bank building had to be abandoned for this reason although the station was situated on a balcony floor made of paving brick.

Permanency—Stations were selected on stone or brick buildings of the most modern type, and the stations were all referenced to different parts of the building, and to bolts in the sidewalks so that the position of any station could be re-established, even if the buildings were remodeled or rebuilt.

Suitability for future work—The Stations were selected as far as possible where there were no higher buildings in the immediate vicinity in order to give an unbroken view around the horizon. Nearly every portion of the city and surrounding suburbs can be seen from some two of the triangulation stations.

In this work a reflecting sphere five inches in diameter was used on some of the shorter lines and was found useful especially when looking westerly through smoke near sunset, but the image thrown was too faint to observe on for more than four or five miles, or when the air was boiling very much.

REPORT ON PRECISE TRAVERSE IN ONTARIO

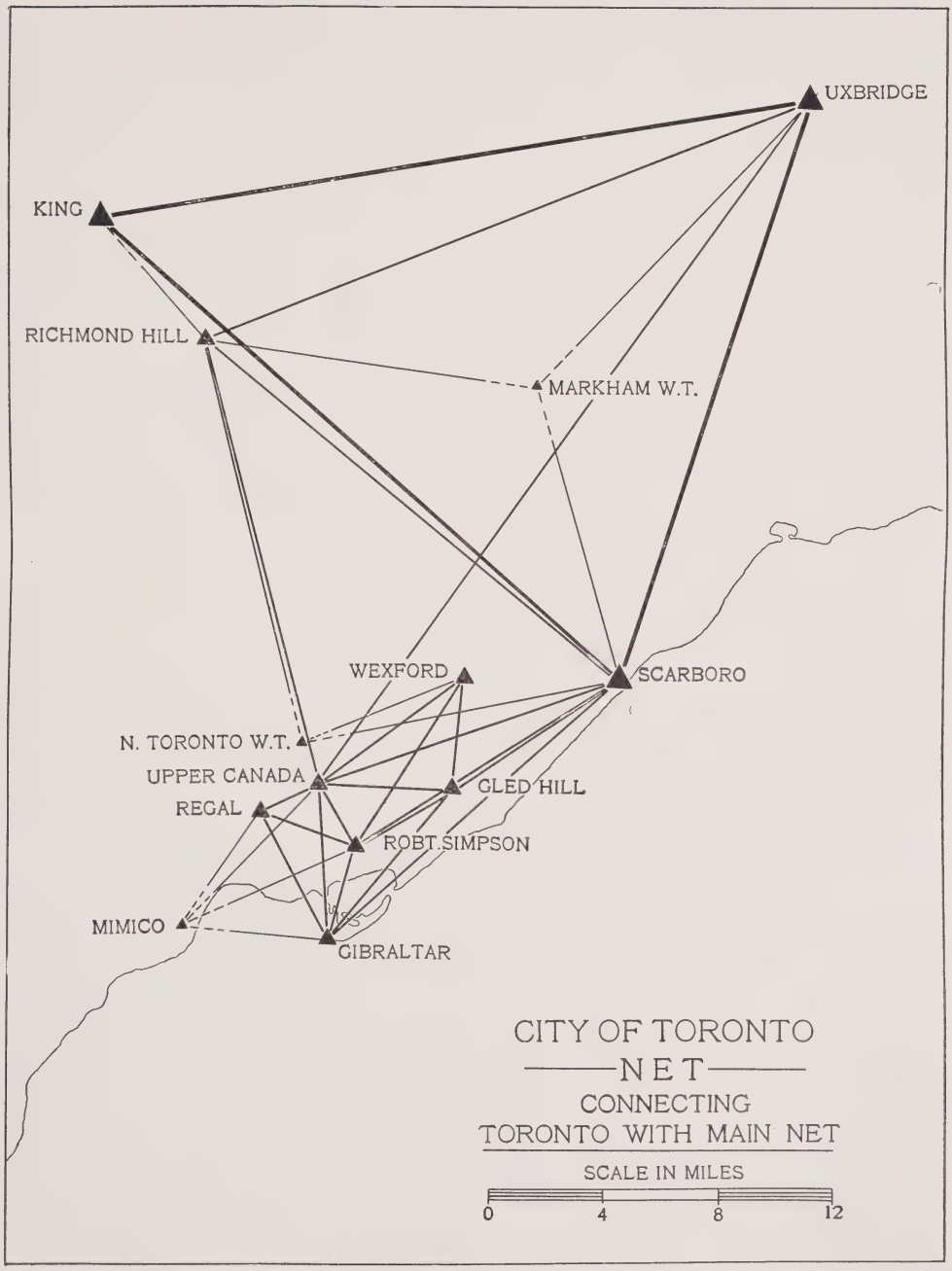
J. M. Riddell, D. & O.L.S.

Object.—The objects of this survey were primarily to determine if it is possible to carry the geographic positions of points through short lines by direct measurement of lengths and angles with a precision which would justify its use in connection with primary triangulation. And secondly, to establish and ascertain the geographic positions of various points in order to control the land and lake surveys in a certain part of Ontario, which has not the necessary control by primary triangulation, due to conditions that were not favourable to that type of survey without excessive cost.

The party, consisting of two assistants, Mr. J. C. Monteith and Mr. E. M. Medlen, and a cook, reported for duty on May 16, at Waterford, Ont., which was to be the starting point for the traverse, and camp was made near Townsend geodetic station on the farm of Mr. W. Chambers.

Reconnaissance.—On May 17, Mr. A. M. Grant and the writer reconnoitred the route for the proposed survey covering the territory from Waterford south to Simcoe along the Lake Erie and Northern railway, thence southeast to Port Dover, and also southwest, from Simcoe to Vittoria and Port Rowan, along the Grand Trunk railway. From Port Rowan a reconnoitre was made for a route to Port Burwell, but conditions were such that it was deemed advisable to abandon this route and proceed from Port Dover to Hamilton, along the Grand Trunk railway, closing on Hamilton geodetic station instead of at Dereham, as it had been originally intended.

The route as finally selected started at Townsend geodetic station, proceeded south to Simcoe along the L. E. & N. railway, thence to Vittoria along the Grand Trunk railway, and from there by highway to Fishers Glen, establishing a point on a high bluff near the shore, from which a connection could be made to Port Dover, Long Point lighthouse and another station on Long Point.


UXBRIDGE
KING
RICHMOND HILL
MARKHAM W.T.
WEXFORD
SCARBORO
N. TORONTO W.T.
UPPER CANADA
GLED HILL
REGAL
ROBT.SIMPSON
MIMICO
GIBRALTAR
CITY OF TORONTO
NET
CONNECTING
TORONTO WITH MAIN NET
SCALE IN MILES
0
4
8
12

At Fishers Glen the traverse came to an end and we backed up to Simcoe proceeding from there to Port Dover along the L. E. & N. railway, and established a point there to connect with the one previously established at Fishers Glen, thus establishing a base from which it is possible to triangulate to Long Point.

From Port Dover the route lay along the Grand Trunk railway, through Jarvis, Hagersville and Caledonia and finally left the railway a short distance south of the rock cut into Hamilton and proceeded by highway finishing at the geodetic point on the mountain at Hamilton.

During the reconnaissance the stations were not finally selected—merely the general route laid out and each station had to be located subsequently which meant that a second and more accurate reconnaissance was necessary for each station during the progress of the work.

System of Survey.—The system of survey finally adopted after careful consideration of all features was to have two separate lines and in order to avoid confusion these will be designated as Traverse line and Azimuth line and the stations as Traverse and Azimuth stations.

The traverse line was surveyed in the usual manner using the utmost care in the measurement of the lengths and angles and the azimuth line was used merely to carry the bearing or azimuth from Townsend through to Hamilton, providing a check at each azimuth station on the azimuth as carried through the traverse lines.

Wherever possible the traverse line followed the railway, the measurements being made with a 50-meter Invar tape, No. 13814, co-efficient of expansion 0.0000085 per 1° C, under a tension of 12 kilogrammes. The measurement was carried forward by marking the position of the ends of the tape on a small wooden peg driven firmly into the ballast midway between the rails. The pegs were driven flush with the surface and in consequence the tape was on the flat at all times, except at the end of tangents or when proceeding around a curve.

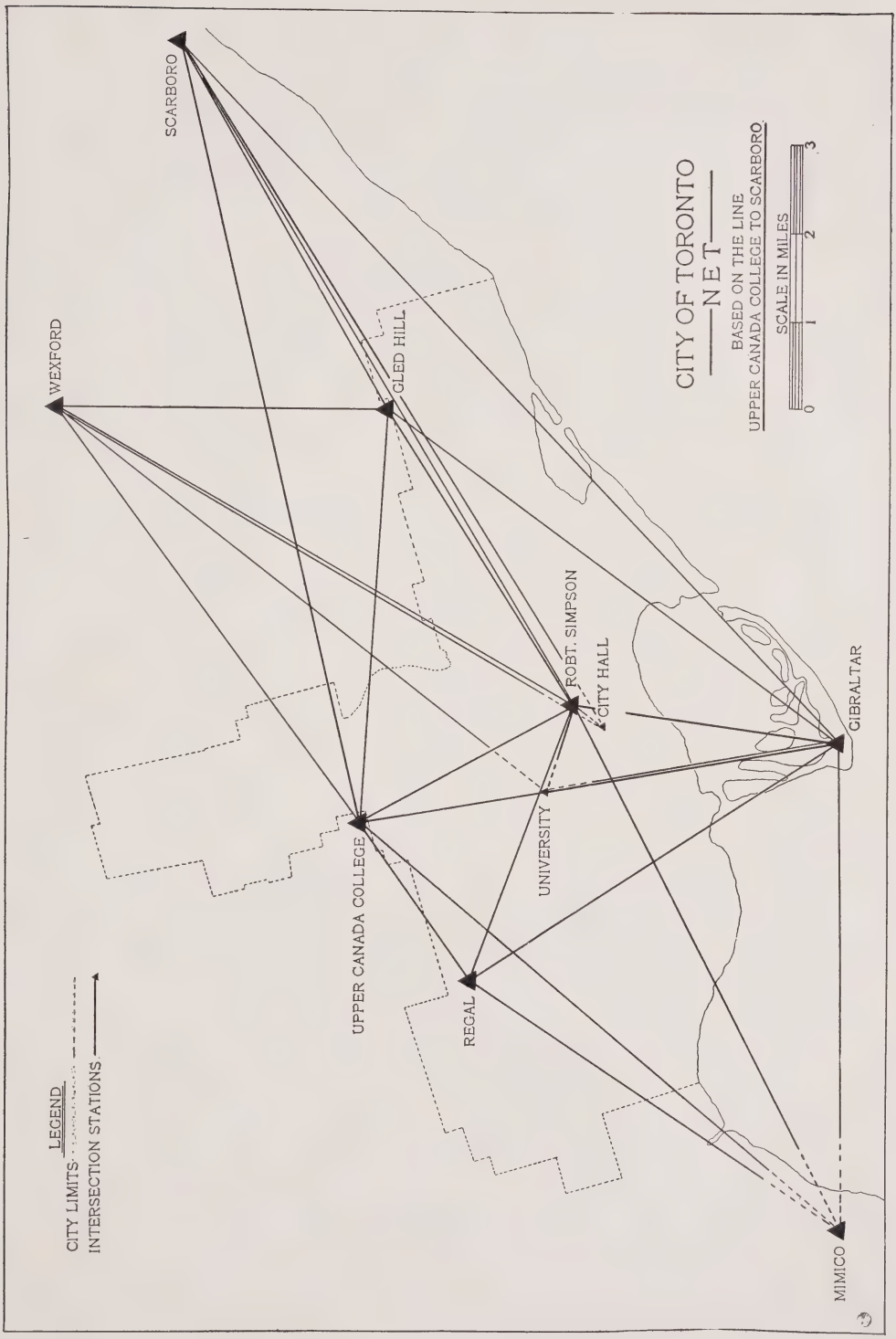
All set ups were measured with either a 50-foot or a 200-foot steel tape and the 200-foot steel was also used under a tension of 8 kilos. to make a direct comparison of the length of each section of the traverse, thus eliminating any bulk error. The slope of each tape length was measured with either an Abney level or with a 6¼-inch Berger transit.

The total length of line measured is approximately 75 miles and on account of check measurements and re-measurements the total amount of measuring would be in the vicinity of 180 miles.

A careful comparison of the measurement of various sections of the traverse was made with the Invar and Steel tapes and from the results it was concluded that in certain cases under varying conditions of temperature, the steel is not to be depended upon for the most precise work; this confirms the previous experience that the thermometers do not correctly register the temperature of the tapes at the instant when the measurement is made. The tape is carried supported at some distance from the ground after each measurement and it is reasonable to expect that a sensitive thermometer will pick up the temperature of the ground somewhat faster when the tape is laid thereon. Two thermometers were used, one at the forward end, and one at the rear end of the tape, and in cases where part of the tape lay in the sun and part in shade a difference of as much as 6 degrees has been noted, this may also contribute in some way to an error in length when the mean is used as the correct temperature of the tape; and where an error of two or three degrees does not appreciably affect the length of a 50-meter tape with a low co-efficient of expansion, such an error would cause a very great discrepancy in the length obtained with a steel tape. The following results of the measurement of a section show how appreciable this is liable to be:—

1st Measurement.	2nd Measurement, with Invar Tape, No. 13814.
12225.8855	12225.9257

1st Measurement.	2nd Measurement.	3rd Measurement with 200-ft. steel
12225.2352	12224.8600	12225.7600


CITY OF TORONTO
NET
BASED ON THE LINE
UPPER CANADA COLLEGE TO SCARBORO
SCALE IN MILES
0
1
2
3
LEGEND
CITY LIMITS
INTERSECTION STATIONS
SCARBORO
WEXFORD
GLED HILL
ROBT. SIMPSON
CITY HALL
GIBRALTAR
UNIVERSITY
UPPER CANADA COLLEGE
REGAL
MIMICO

From the above the measurements of the section with the invar show a discrepancy of 1 in 300,000 whereas the steel shows as much as 1 in 24,000.

In addition to the above mentioned tapes, a twenty-five metre Invar tape was carried in the field as a standard and at intervals a comparison was made for the purpose of determining any change in the length of the working tapes.

The angles at the traverse stations were measured with a 6¼-inch Berger theodolite, reading to 10 seconds. The repetition method of six readings on the angle and six on the explement was used, giving an angle with a probable error of less than two seconds. In all, the angles at 140 traverse stations were measured using this method, and in very few cases were the computed corrections to these angles more than one second.

The azimuth stations were carefully selected and prepared and the directions at these stations were observed with a 12-inch Kern theodolite (a three micrometer instrument reading to single seconds). Eight positions were observed as in secondary triangulation and in carrying the azimuth through thirty-four lines whose length varied from six hundred metres to four miles, the error was found to be 4.1 seconds.

The position of each azimuth station was carefully selected in order to obtain as long lines as possible and also with a view to facilitate either direct measurement from some traverse station or to allow of its being cut in from two or more traverse stations.

Each azimuth station is marked by a copper bolt or copper wire set in a tile filled with concrete. The top of the tile is set from six inches to eighteen inches from the surface of the ground, depending on its location in either cultivated or uncultivated ground.

Reference monuments have been placed at certain of the azimuth stations to allow them to be more readily found, these consist of a column of concrete about five feet high set into the ground, the top is squared and projects about six inches above the surface. In the top of this column a copper reference bolt with plate is set with the arrow pointing to the true station.

In August the writer had the privilege of visiting the American precise traverse party under Mr. C. L. Garner, of the United States Coast and Geodetic Survey, who was at that time doing work in Wisconsin, and it was a revelation to find that his party consisted of twenty-five men, with eight motor trucks, five railway speeders, seventeen tents, and various equipment, in comparison to the Canadian party of three men and one half-ton Ford truck. With such a large party it was possible for Mr. Garner to cover a considerable distance in a season's work with ease while the writer was able to do but seventy-five miles with considerable difficulty.

Summary.—Taking all things into consideration, the amount of work accomplished with such a small party was enormous.

Forty-four stations were selected, prepared and occupied with the 12-inch instrument and directions observed to all prominent public buildings and lighthouses that it was possible to observe from those stations.

One hundred and forty traverse stations were occupied with the Berger transit with a total of approximately two hundred and fifty measured angles.

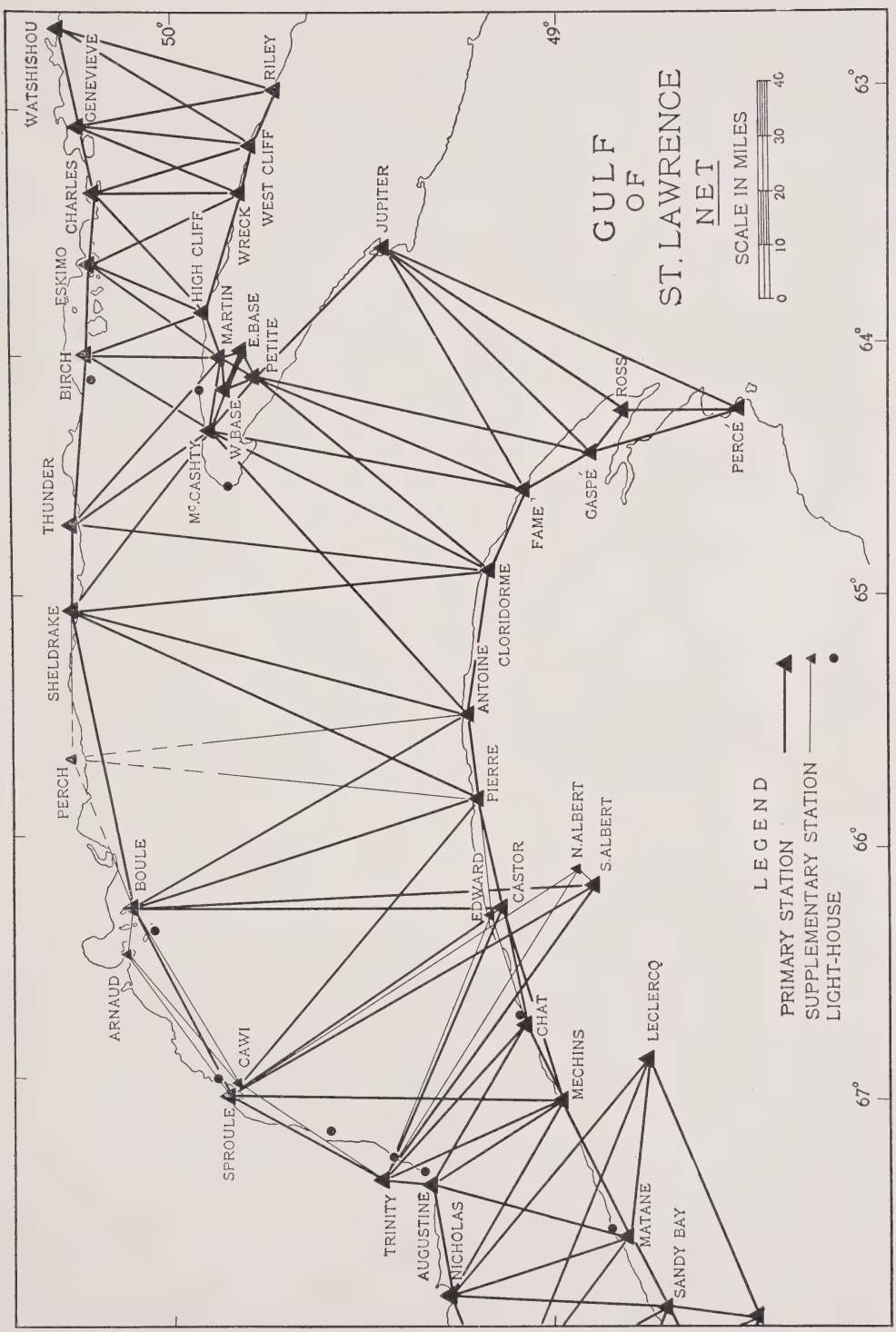
Seventy-five miles of line was measured with the greatest accuracy possible.

And in addition, all measurements were reduced in the field and the co-ordinates computed in order that a minimum amount of computation would be necessary in the office.

TRIANGULATION ON THE LOWER ST. LAWRENCE AND GULF AREA

W. C. Murdie

General Progress.—The field season for the tower building party extended from May 6 to November 15, while others were in the field for a shorter period. During the


GULF
OF
ST. LAWRENCE
NET
SCALE IN MILES
0 10 20 30 40
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LIGHT-HOUSE
WATSHISHOU
GENEVIEVE
CHARLES
ESKIMO
BIRCH
RILEY
WEST CLIFF
WRECK
HIGH CLIFF
MARTIN
E.BASE
PETITE
W.BASE
McCASHTY
THUNDER
SHELDRAKE
PERCH
BOULE
ARNAUD
CAWI
SPROULE
TRINITY
AUGUSTINE
NICHOLAS
JUPITER
ROSS
PERCÉ
GASPÉ
FAME
CLORIDORME
ANTOINE
PIERRE
EDWARD
CASTOR
N.ALBERT
S.ALBERT
CHAT
MECHINS
LECLERCQ
MATANE
SANDY BAY
50°
49°
67°
66°
65°
64°
63°

season of 1921 the primary triangulation net was extended to cover that portion of the Gulf bounded approximately by a line joining Cap-Chat lighthouse on the south shore and Pointe-des-Monts lighthouse on the north shore as its westerly boundary, and a line from Madeleine lighthouse on the south shore to Thunder river on the north shore as its easterly boundary. The distance between these two boundaries is about eighty-five miles, or in other words the area covered by last season's work was approximately six thousand square miles.

During the season nine primary and four secondary stations were occupied and completed while two other primary stations were almost completed. A fifth secondary station was observed on from four primary stations with primary accuracy thereby eliminating the necessity of occupying this secondary station.

Description of scheme and country.—The primary net is built up of a series of quadrilaterals (lying side by side) whose general shape is more or less rectangular with the length equal to two or three times the breadth and at the same time lying in a northerly direction. The vertices of these quadrilaterals are located on prominent points within a few miles of the north and south shores of the Gulf. The north shore is low and and only has a few prominent hills whose elevations would exceed two or three hundred feet, while the south shore is rough and rolling with many hills with elevations ranging up to sixteen or eighteen hundred feet.

Organization:

(*a*) Engineer-in-charge of operations with headquarters on C.G.S. "*Gulnare.*"
(*b*) Two parties hereinafter mentioned as the north and south shore parties to make geodetic measurements and observations comprising: Engineer-in-charge, recorder, helper and cook.
(*c*) One tower-building party comprising: Engineer-in-charge, six carpenters and cook.
(*d*) Six lightkeeping parties each comprising a lightkeeper and helper to operate signal lights.
(*e*) Ship party: C.G.S. "*Gulnare,*" length 137 feet, beam 20 feet, draft 12 feet 6 inches with a complement of six officers and eighteen other ranks, together with a wireless officer.

Preparations for Season.—The first section of the land party under Mr. J. H. Kihl arrived at Rimouski wharf on May 7, to prepare the training camp. Tents were pitched on an ideal camp site on a mill yard near the end of Rimouski wharf. On May 11, the remainder of the party including Messrs. C. H. Ney and C. K. McElroy arrived and immediately went into camp. The various parties were allotted their equipment, including tents, instruments, etc., and by the second day everything was ready to commence training. All members of the party, with the exception of the tower-building party, were given concentrated instruction in signalling, use and care of instruments and equipment. At the same time the tower-builders were getting their outfit in order.

It may be noted that during the winter months necessary repairs to make the "*Gulnare*" seaworthy were executed by H. M. C. Dockyard, Halifax, and the permanent staff of the "*Gulnare.*" Ship stores for the deck, engine-room and steward's department were ordered and brought on board and when the ship sailed for Rimouski on May 12 everything was in first class condition.

On May 15 C.G.S. "*Gulnare*" docked at Rimouski wharf from Halifax, where she had been stationed since the close of the 1920 field season. Coaling operations were completed and at midnight on May 18 the "*Gulnare*" sailed with the various parties (including the north and south shore parties, the tower-building party, six lightkeeping parties and Mr. J. Perrier of Mr. Menzies' reconnaissance party) on board. The distribution of these various parties was completed within forty hours, a distance of about two hundred miles having been covered. It may be noted that practically

all parties were landed by boat on the beach and in that way one may see opportunities for accounting for much more time than if men and equipment were landed on wharfs.

North and South Shore parties under Messrs. Kihl and Ney.—Throughout the season the work of these parties was, generally speaking, that of making geodetic measurements and observations. It may be noted, however, that besides this, circumstances required some extra work to be done such as the re-erection of the tower at Mechin primary geodetic station, which had suffered serious damage from the storms of the previous winter. Several of the stations were difficult of access. For example, in the month of July the Mount Albert stations were occupied. As the country in that area was wild and undeveloped it necessarily followed that there was considerable hard work connected with transporting the engineer's outfit to the main camp on the Ste. Anne river, a distance of about thirty-five miles from the St. Lawrence river. From main camp the party had a pack of about nine miles to the Albert primary geodetic station over a rough trail necessitating a climb of about three thousand feet.

Practically all instrumental work was done by night with the exception of a certain amount of secondary work on churches or lighthouses or where prominent land marks were tied into our geodetic stations.

During the season twenty-nine triangles were closed with a maximum closing error of 2·01 seconds, and an average closing error of 0·78 second.

Tower Building Party under Mr. C. K. McElroy.—This party commenced operations on May 19 at Castor primary geodetic station and from that point they worked eastward along the Gaspé coast. Towers were erected, concrete piers constructed, and trails prepared at four primary stations. On July 22 Mr. McElroy and party were transported, via C.G.S. "*Gulnare*," to Anticosti. Both on the Gaspé coast and on the island of Anticosti there was considerable difficulty in securing suitable materials for towers and in all cases the timber had to be cut in the woods and taken to the tower site either by man packing or by horse (where such was available). As a result of the season's operations the following work was accomplished:—

1. Towers erected—2 at 80 feet.
   2 at 75 "
   4 at 50 "
   1 at 30 "
   1 at 25 "
2. Ten concrete piers were constructed.
3. Trails were prepared leading to all stations and vistas were opened up where necessary.

In several cases on Anticosti the trails to the stations traversed moderately rolling ground, covered by bush and windfalls, or swamps, and a great deal of time and work had to be spent in cutting passages through these windfalls. It may be noted that on account of the heavy equipment required at the erection of the larger towers it made it more necessary to prepare good trails over which this equipment had to be packed.

The tower building party completed the season's programme of work early in November. The equipment was stored at Rimouski and Mr. McElroy returned to Ottawa, while the remainder of the party was disbanded.

General Comments.—During the months of May and June weather conditions for observing could be considered as favourable, but on or about July 12, as a result of dry weather, forest fires became plentiful and the resulting smoke, together with haze and fog completely tied up the work of making geodetic observations until about August 5. After that date observing conditions were fairly good. It may be noted, nevertheless, that horizontal refraction interferred more or less throughout the season.

With the exception of cases of emergency on short lines (where acetylene lamps were used) electric lamps were employed throughout. Two styles, namely the United States Coast and Geodetic, and the Ford headlight patterns, were used and proved to be satisfactory. The electric lamps were lighted by No. 6 dry cells, arranged in batteries of 12 or 15. Two styles of special bulbs were used, namely, a small one taking 3.8 volts and a large one requiring 6 to 8 volts. The former style of bulb was used over the shorter lines, while the latter was used over lines from fifty to eighty-five miles in length.

The work of the *"Gulnare"* was to transport the various parties from station to station, as required, and to keep these parties supplied with all requirements, such as provisions, etc. Besides this, the *"Gulnare"* made several extra trips to transport other Geodetic Survey parties, such as Professor L. B. Stewart's reconnaissance party. Mr. F. A. McDiarmid's astronomic party and Mr. Robb's base line party.

In all, the distance travelled by the *"Gulnare"* during the season was over eleven thousand (11,000) miles. As there are no roads on the north shore and since the one road on the south shore was bad, it follows that the only means of transporting men and equipment from station to station was by water. For this purpose the *"Gulnare"* proved very satisfactory. She was seaworthy and there were no delays on account of storms, as would have been the case if a smaller and less seaworthy ship had been employed. The Gulf, in the region worked over, is about seventy-five miles wide, and there are very few harbours to give protection against the violent storms which are liable to occur.

Co-operation with Hydrographic and other Surveys.—Throughout the season field conputations were kept up to date and whenever calls for preliminary results of geodetic positions of prominent hydrographic stations or light houses were made it was usually possible to give these out with a minimum amount of delay.

Early in the season a request was received from the Geological Survey for a station on Mount Albert, in the Shickshock Range, and prior to commencing his own work in New Brunswick, Mr. J. W. Menzies visited that mountain with reference to choosing the station. Later on, upon further investigation, it was decided to establish both a primary and a secondary station on Mount Albert and as a result of the arrangements made, we now have a geodetic position, a length and an azimuth from which the Geological Survey may tie in their work.

Visitors.—During the season official inspections were made by Messrs. Ogilvie, Peters and Rannie.

Methods of Communication.—As the *"Gulnare"* was provided with wireless and the majority of the lightkeepers were qualified army signallers, this enabled all parties to keep in close touch with one another and at all times to keep the engineer in charge posted as to their progress and requirements. Messages were signalled by lamp to the party stationed nearest to a land telegraph station. These were then forwarded to the nearest Marconi station, which in turn, transmitted them by wireless to the *"Gulnare."* The wireless and signalling in this way proved invaluable when it came to moving parties from one station to another, by eliminating delays or by preventing duplication of trips. It may be noted that regardless of the location of the *"Gulnare,"* the engineer in charge was kept in touch with the progress of the work and could arrange to have the *"Gulnare"* meet parties as soon as they were ready to be moved, thereby eliminating all possible delay.

In addition to the above the engineers in charge at times signalled the results of their observations to one another which was very advantageous.

Ellis Bay is the main centre on Anticosti and from that point parties are taken inland to the primary stations of the base net via the standard gauge railway belonging to the Administration of the Island of Anticosti. A motor hand car was used on this railway and gave excellent service. As the interior of the island is

covered by woods, windfalls and swamps, and without waggon roads, it is difficult to traverse with equipment and supplies, so that the fact of finding a railway in the area in which our stations are located has already and will in future eliminate a great deal of hard packing and at the same time will be a great time saver.

Closing of Season.—On October 6 the *"Gulnare"* returned to Rimouski Wharf with the entire land party, with the exception of the tower building party, on board; the equipment was stored, and with the exception of Mr. Kihl and four others, the party was disbanded. Mr. Kihl then proceeded with his party of four to Leclercq primary geodetic station in the Shickshock Mountains, to construct a pier. The roads at that time of year were very bad and the work of reaching that station required a considerable amount of time and hard work. After that the monumenting party erected concrete piers at Mount Joli, Pistoles and Citadel primary geodetic stations and at Rivière-du-Loup and Trois secondary stations. This party returned to Rimouski on November 2; their equipment was stored and the party disbanded.

C.G.S. *"Gulnare"* returned to Halifax on October 14. Upon her arrival everything was put in order for the ship to go into winter quarters, and the temporary members of the crew paid off.

RECONNAISSANCE OF THE LOWER ST. LAWRENCE

Professor Louis B. Stewart

Having been informed that the *"Gulnare"* would be at Rimouski on May 25, ready to leave for the North Shore, movements were timed so as to arrive there on that date, and Mr. Coughlan, who was to assist during the summer, arrived at the same time. The party at once went on board the "*Gulnare,*" which pulled out on the same day. The *"Gulnare"* first called at Edward, took Mr. Kihl on board, and landed him the following morning at Trinity; then steamed on to Seven Islands, and in the afternoon of the 26th anchored beside Great Boule.

Having been instructed to locate a station between those at Boule and Sheldrake, established the previous summer, accompanied by Mr. Murdie, the party climbed to the station at Boule to examine the shore easterly from there.

As no promising point for a station could be seen the party set out the following morning and coasted along the shore, and at about thirty miles from Boule succeeded in finding a satisfactory point about half a mile inland from Bellefleurs Cove, where the station, Perch, was established. Setting out for Anticosti island, the engineers landed at Ellis Bay and the *"Gulnare"* left in the evening for the south shore.

The most easterly stations established on the island during the previous season were North and South stations, forming part of the base net. North station was intended to connect with stations on the north and south shores of the Gulf, and with others to be established on the north and south shores of the island. The party accordingly set out easterly from Ellis Bay on the 30th in a small boat which was going in that direction with supplies, with the object of selecting the site for a station to serve as a connecting link between North station and one to be located near Jupiter river. We landed and pitched camp near the game warden's house at the mouth of the Ste. Marie river.

After several days spent in looking over the country between that river and the Becscie, and failing to find a point suitable for a station, it was decided to go on to Jupiter river, establish the station there, and from that point examine the country looking westerly. Taking advantage of another fishing boat going in that direction the party, therefore, went to Jupiter river, where it was not difficult to find a suitable point for a station. From the site selected, it was possible, on an exceptionally clear day, to see Percé Mountain rising like an island out of the sea. On looking westerly, the most likely looking hill for a station proved to be that on which Petite station was afterwards located, so that it became unnecessary to look further for an intermediate station between the base net and Jupiter.

On June 11 the party returned to Ellis Bay, taking advantage again of a small boat going in that direction, and on the 13th moved camp by hand-car to mileage 15 on the Anticosti railway, a point within easy distance of the stations of the base net.

It was soon evident that North station must be abandoned, as it was found that a light shown at Fame was invisible at North, though the south shore in the direction of Fame could be clearly seen at the latter station. It is probable, however, that the land seen was the higher ground beyond the station. In addition to this, the outlook easterly from North station was not all that could be desired. A new station, Martin, was therefore established about two miles east of North; from it High Cliff Point could be seen, but not the stations on the south shore of the Gulf. It was, therefore, necessary to discard finally the original plan of observing the stations on both shores from a single station of the base net. Other changes consisted in replacing South station by Petite, above referred to, from which a direct view could be had to Jupiter; also in changing the position of McCashty to a hill a mile and a half to the north of that on which the station had been established the previous season. This latter change made it possible to use Inner Birch island for a station, that island being invisible from the more southerly hill.

The above alterations in the base net permitted, in fact necessitated, the addition of two miles to the easterly end of the base, thus extending it to the point originally selected for East Base by Mr. McDiarmid.

During the months of June and July much delay was caused by the smoke of forest fires, a total of three weeks being lost from this cause alone, so that it was near the end of July before the work in connection with the base net was completed.

On July 29 the party set out from Ellis Bay for the north shore of the island in a fishing boat hired from the Anticosti Administration, and after a few days spent at Grand McCashty crossed over to Birch island to take some observations in an easterly direction from there. Mingan island was also examined in order to be prepared for the necessity of using it for a station.

As a strong north-westerly wind had now arisen it was not safe to return to the Anticosti shore at once; Eskimo point was examined as to the possibilities for a station in its vicinity. The most likely point seemed to be Eskimo island, locally known as Harbour island, but on the day it was visited the wind was too strong for accurate observation from a tree-top, so that one could not be certain of seeing Birch island over Large island. Charles island could be easily seen over Clearwater point; it was arranged, however, to leave the location of the station near Eskimo point undecided for the present.

On August 10, the weather having improved, we set out for Anticosti, heading for High Cliff point. Landing immediately to the west of the point, the party climbed to the summit and established the station there. Between the above date and the 21st, the additional stations, Wreck, West Cliff and Riley, were also established on the north shore of Anticosti. The last-named station is situated on the east side of McDonald's Cove and about three miles west of Charleton point lighthouse, which can be observed from it. Cape Observation is also visible, so that a station may be located there if desired.

On the 22nd the party coasted back to Wreck station, the position of which was changed, and the following day crossed to Eskimo Point, being obliged to depend upon sails and a very light wind, the engine refusing to work. This boat, with the two men in charge, was sent back to Ellis Bay, as previously arranged, and another boat and two men hired at Eskimo Point for the remainder of the work on the north shore.

A re-examination of Eskimo island under good weather conditions showed that Birch island is just visible over the nearer island. After establishing the station at the highest point of the island, near its northwest corner, the party set out the same

day and ran to Charles island, and the following day established the station there, while the boat returned to Eskimo Point for supplies. The next morning the site of the station on Ste. Genevieve island was marked on the summit of a cliff facing the north.

The following morning was employed in triangulating the height and distance of a prominent hill about five miles inland, known as Blue mountain. Two days after a station was established on the summit of a bare rocky hill just to the east of the river mouth. This hill, though only 150 feet in height, appears as a conspicuous object for many miles up and down the coast, a fact which emphasizes the general flatness of that part of the shore. Looking easterly from its summit the shore appears extremely low, with a very gradual rise inland, so that it is highly improbable that any portion of it, east of Watshishu, can be seen from Riley or Cape Observation. The triangulation easterly from the line between Riley and Watshishu will therefore have to be carried on independently on the two shores.

Eskimo Point was reached again on August 31, after an absence of a week, and as previously arranged, a wireless message was sent to Mr. Murdie. The *"Gulnare"* arrived on September 4, and after making some calls landed the party at Rimouski on the 7th. The following day Gaspé was reached.

The first thing to be done was to locate a station, to the southwest of the town to form a quadrilateral with the stations Gaspé, Ross and Percé. At Gaspé a fire ranger's observing tower had been built on a high hill near the source of the York river, and it was decided to look at it; on the 10th, after motoring as far in this direction as the roads would allow, the party was turned back by rain. On further enquiry it was learned that the tower is reached by following a northerly branch of the York river, and it was therefore too far to the north to be of any use for the purpose in view. Gaspé and Percé stations were then visited in turn and a number of points visible from both were picked out, that might serve for the new station. The two most likely points are situated just beyond the source of the Malbaie river, at distances of 27 and 30 miles from Percé station, and can probably be most easily reached by following the valley of that river. Two other prominent points of considerable height are situated at distances of 37 to 40 miles, respectively, from Percé, on an astronomic bearing 280°, one of which might be useful if it were desired to extend the triagulation into the interior.

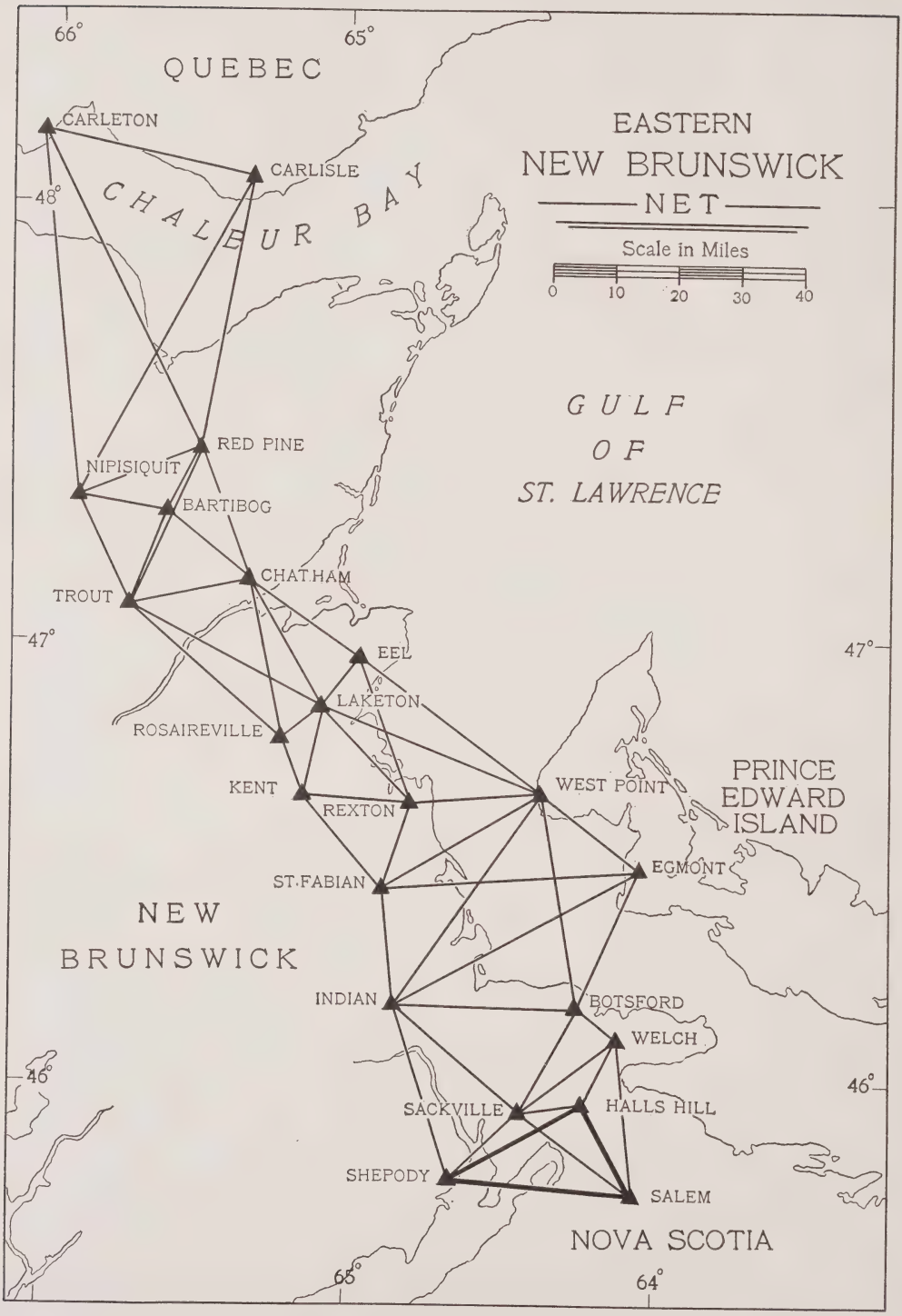
There was not sufficient time left to reach the nearest of these points, so the party disbanded on September 16.

RECONNAISSANCE IN NEW BRUNSWICK

J. W. Menzies

The season's work started on May 16 and the remainder of the month was spent in reconnaissance in connection with the cutting in of a primary station on Mt. Albert. This mountain is situated in the Gaspé peninsula about thirty-five miles up the Ste. Anne river. The Ste. Anne river flows into the St. Lawrence river about forty miles east of Matane. This station is to be used by the Geological Survey as a starting point for some surveys that they intend making to the west of Mt. Albert. The primary station was placed on the west side of the top of the mountain. Afterwards the observing party put in a secondary point on the east side of the top about three miles away thereby giving the Geological Survey a base and an azimuth to start off with. These stations could only be cut in from the north shore of the Gulf of St. Lawrence as the lines to the stations on the south shore were blocked.

After completing this reconnaissance the engineer proceeded to Newcastle, New Brunswick, and made a revision of reconnaissance along the east coast of New Brunswick between Rexton and Chatham. At this point, the previous reconnaissance was somewhat weak owing to a short going ahead line. One new station was put in and three were eliminated while the positions of four others were changed. A diagram of the latest scheme accompanies this report on page 56.


66°
65°
QUEBEC
CARLETON
CARLISLE
48°
CHALEUR BAY
EASTERN
NEW BRUNSWICK
NET
Scale in Miles
0 10 20 30 40
GULF
OF
ST. LAWRENCE
RED PINE
NIPISIQUIT
BARTIBOG
CHATHAM
TROUT
47°
EEL
LAKETON
ROSAIREVILLE
KENT
REXTON
WEST POINT
PRINCE
EDWARD
ISLAND
EGMONT
ST.FABIAN
NEW
BRUNSWICK
INDIAN
BOTSFORD
WELCH
46°
SACKVILLE
HALLS HILL
SHEPODY
SALEM
NOVA SCOTIA
65°
64°

After making this revision two stations were located temporarily on the south shore of the Gaspé peninsula to connect with the last two stations in New Brunswick, Nipisiguit and Red Pine. These points could not be definitely located at the time as it was uncertain as to whether the line of sight from the tower at Red Pine would come down low enough to enable the stations to be intervisible. This tower has now been built by the New Brunswick Government. In company with Mr. Prince, Provincial Forester, a visit was made to this place in January; it was found that the whole line of the Gaspé peninsula is visible over almost its whole length. From these points the triangulation can be swung to the east to connect up with the St. Lawrence triangulation at the end of the Gaspé peninsula. During this period the progress of the work was much hampered by the hot hazy weather and the smoke from the forest fires which were unusually prevalent.

During the summer an arrangement was entered into between the Superintendent and the Provincial Forester of New Brunswick whereby the provincial government are to build certain of our towers which they desire to use as fire lookouts. These towers combine the features necessary for the purposes of both parties and the cost is to be equally divided. Red Pine and Trout towers have now been built and the portion to be paid is less than what it would have cost to build one for the exclusive use of the survey.

The last month and a half was spent up the Saguenay river preparing the primary stations there so that the observing could be done the first thing in the spring. A forty-foot tower was erected at Ferland station. There are four primary stations in this scheme and then the intention is to step down to a secondary scheme. Price Bros. Lumber Co. was granted permission to use Ferland tower as fire lookout.

DIRECTION MEASUREMENT IN NOVA SCOTIA

J. E. R. Ross

The purpose of the season's work was to extend the primary and supplementary triangulation from near Antigonish, N.S., where it had been discontinued the season before, eastward over Cape Breton island.

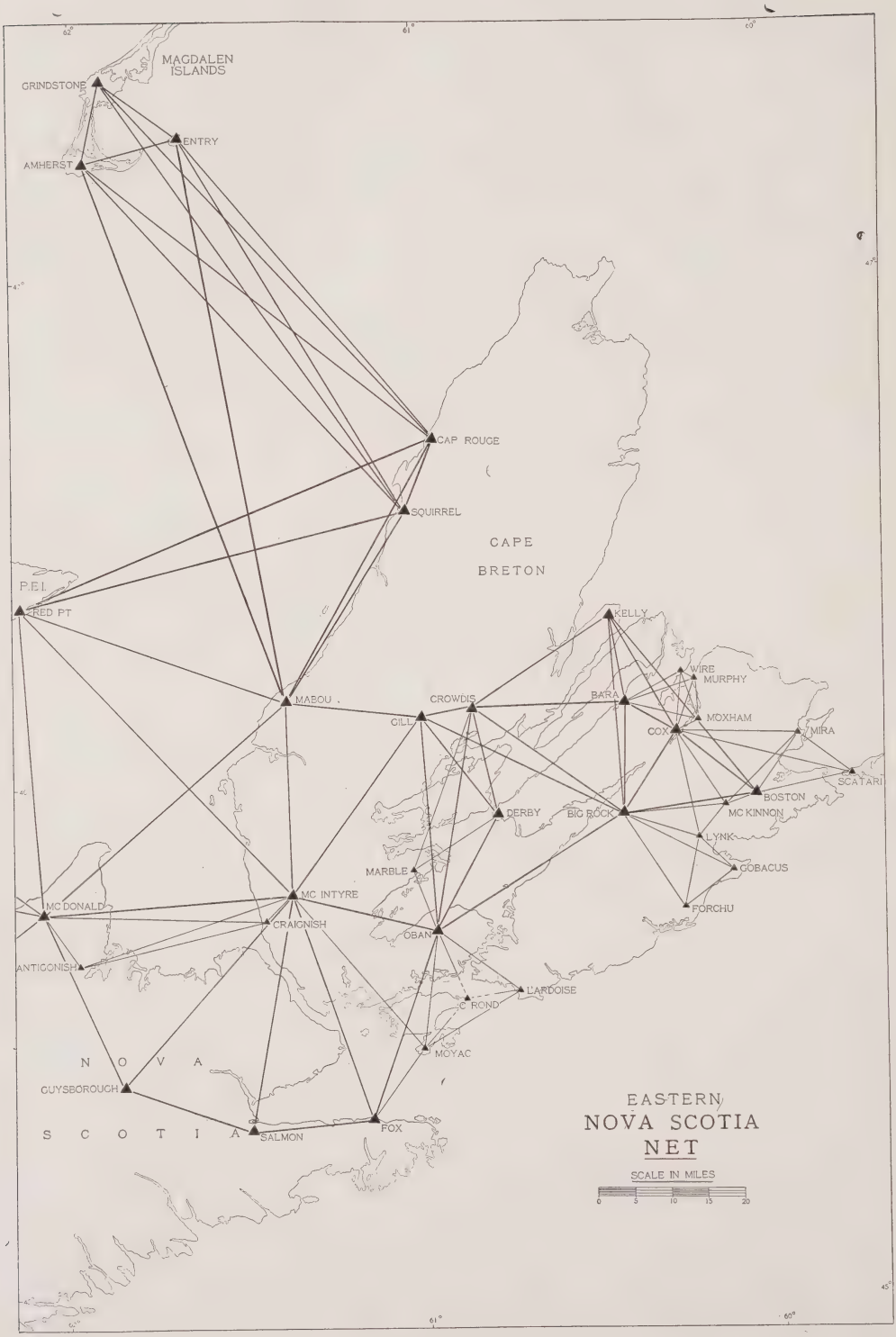
The primary triangulation, an extension of last season's work from the Bay of Fundy, has now been carried as far east as Sydney. It covers the area on both sides of the straits of Canso, and adjoining waters, George bay and Chedabucto bay, thence along the Bras d'Or lakes region to Sydney. The interior area is about 4,000 square miles. It comprises fourteen new stations, of which two, Salmon and Fox, on the south side of Chedabucto bay, are coincident with stations of the same name established by the Hydrographic Survey. In Cape Breton island, south of a line from Antigonish to Sydney, no area now exists which is more than twenty-five miles from a primary control point.

With the view of making some of the control points more accessible, and thereby also increasing the number of points available for topographic control, supplementary triangulation has been carried out in five localities. Unless otherwise mentioned, the observations were made with a 12-inch instrument, using four positions of the circle.

At Antigonish, from the station of the same name, about eight church spires were intersected, which could not be seen from other points. A small scheme with Antigonish as the central point, based on the line McDonald–Antigonish, was put in. Three intersections were thus obtained on all of the church spires. The observing was done with a 6-inch instrument, using six repetitions.

Many of the lighthouses around Madame island were visible from only one primary station. To obtain intersections on as many as possible two points were put in at Moyac and L'Ardoise.

The primary points near the Bras d'Ors are for the most part invisible from the near shore. To render these more easily accessible for traverse surveys and Hydro-


MAGDALEN ISLANDS
GRINDSTONE
ENTRY
AMHERST
CAP ROUGE
SQUIRREL
CAPE BRETON
P.E.I.
RED PT
KELLY
WIRE
MURPHY
MABOU
CROWDIS
BARA
GILL
MOXHAM
COX
MIRA
SCATARI
BOSTON
DERBY
BIG ROCK
MC KINNON
LYNK
MARBLE
GOBACUS
MC INTYRE
MC DONALD
CRAIGNISH
FORCHU
OBAN
ANTIGONISH
L'ARDOISE
C ROND
MOYAC
N O V A
GUYSBOROUGH
S C O T I A
SALMON
FOX
EASTERN
NOVA SCOTIA
NET
SCALE IN MILES
0 5 10 15 20

graphic work a scheme of six stations was introduced around Bras d'Or lake. Many of these points are on the same sites as were used in the first surveys of the lake. The British Admiralty, according to local evidence, used the stations McKenzie Point and The Points, some 60 years ago when charting this lake. No permanent marking was established. Marks have now been established with concrete monuments of the standard size. The work was done with a 6-inch instrument.

The stations Wire, Murphy, Moxham of the Sydney Harbour triangulation, conducted by the Hydrographic Survey, were connected to our primary scheme. The astronomic pier in Sydney is now also established geodetically.

The large territory between Sydney and Louisburg was covered by a net of six points. Its main feature is the number of lighthouses along the southeast coast, which could be intersected from it.

The organization for the field work was the same as for the past season, i.e., Chief Engineer and Assistant, 2 Direction Measurement parties, each composed of Engineer, Recorder and Cook, and 9 Lightkeepers. The Direction Measurement parties were in charge of C. H. Brabazon and L. N. Wadlin.

Mr. Brabazon observed the stations Salmon and Fox on Chedabucto bay, Cape Mabou and then worked along the northern side of the scheme towards Sydney, a total of nine primary stations. He also occupied for observing, the supplementary scheme of Sydney Harbour, in addition to Marble mountain, of the Bras d'Or lake work, a total of five stations.

Mr. Wadlin occupied the primary stations, Guysboro, McIntyre, Oban, Big Rock, Boston and the supplementary stations, Antigonish, Craignish, Moyac and L'Ardoise, at the western end of the primary net, as well as the six stations comprised in the Sydney–Louisburg area. He re-occupied McIntyre and Mabou stations to effect better reading for the line McIntyre–Mabou, as the triangle closures involving this line were quite large. It was found that this line passed so close to one of the struts as to be deflected. Upon removal of the strut no difficulty was experienced in obtaining satisfactory readings.

Weather conditions during the past season were unusually favourable for speedy prosecution of the work. The success of the work is always largely dependent on weather conditions. The speed is due almost entirely to the faithfulness and industry of the observers in making use of the clear weather to the limit of their endurance.

The following is a summary of the results obtained:—

14 Primary stations established.
15 Supplementary stations occupied with 12-inch instrument.
9 Supplementary stations occupied with 6-inch instrument.
25 Intersected points—lighthouses and churchspires.

The list of lighthouses, with three or more intersections, or a complete check on their determination is as follows:—

Cape George, Henry Island, Cranberry Island, West Arichat, Marache Point, Green Island, Cape Rond, Saint Esprit Island, Fourchu Island, Guyon Island, Scatari Island East, Flint Island, Flat Point, South Bar Sydney Harbour.

It has been noticed that on many stations a further improvement of the method of marking stations seems desirable. The use of the disk bolt has made recovery of the actual point very easy, where the rock surface is uncovered, prominent and of fairly small area. This, however, is not the case where the rock surface is flat, lies on a barren and where the station site has been cleared of marsh or bog vegetation, as it is apt to become covered within a few years and thus rendered almost impossible of recovery. It is suggested that the regulation concrete monument be used to mark such stations, or on very difficult stations, that they be at least marked by a cube of concrete a foot to a side.

In the proposed connection with the Magdalen islands it will be advisable to employ the electric light in place of the acetylene light. Many of the lines are 80 miles in length. The extra brightness of the electric lamp will tend to give easier

pointings under the usual weather conditions prevailing along the coast, and thereby increase the speed. This might not be so noticeable on the longer lines as weather conditions will have to be favourable over a large area in order to see the lights at all, but over the shorter lines it should effect a material saving in time.

RECONNAISSANCE IN THE MARITIME PROVINCES

H. P. Moulton, Geodetic Engineer

The season commenced with the fiscal year, on April 1, several weeks before the snow had gone from the thick bush and highlands in the Maritime Provinces.

The first part of the month was spent in visiting some of the triangulation stations near St. John, N.B., the object being to obtain fuller descriptions of the stations and to place reference bolts.

After crossing the bay of Fundy about the middle of April, a visit was made to station Annapolis. Here it was found that the old tower had been down for some time and the station mark (small copper bolt) was buried under moss and earth so that a stranger would have had difficulty in locating it. Accordingly, Mr. N. E. Kelly, then at Little River, N.S., proceeded to construct a concrete survey monument at this point and also a small reference pier at a lot corner near the Geodetic station.

The engineer next went to Cape Breton island to continue the reconnaissance in that area, and Mr. W. N. McGrath arrived at Port Hawkesbury about the last of April.

The months of May, June and July were spent mostly on supplementary work in Richmond and Cape Breton counties. In addition to the primary stations in these counties, twelve secondary stations, six of which were ground stations and six required towers averaging 36 feet in height, were located.

From these stations three intersections were obtained on all the main lighthouses, about twelve in number, as well as many other points in the two counties.

Two ground stations, Moxham and Murphy, were located in Sydney, and one (Station Wire) in North Sydney. These stations are coincident with Hydrographic Survey stations of the same names, and they furnish good control for the Sydney area.

At Louisburg a Marconi Mast over 300 feet in height was used as a station. This point is about a mile distant from Fort Louisburg. The few old stone buildings that mark this historic spot are now in ruins and serve only as a shelter for domestic animals.

Towards the end of July Mr. F. H. Peters made a tour of inspection. A good part of Cape Breton island was covered and both the observing parties and the tower building party were visited. At this time weather conditions were very unfavourable. Prevailing fogs, smoke and hazy weather greatly hindered the progress of the reconnaissance and observing parties. Continued dry weather favoured the tower building party. They were held up only two or three days during the entire season and accomplished an exceptionally good season's work.

The offer of a hydroplane was gladly accepted, but the Air Board later found that they could not supply it.

In August the party went to Pictou and from there by boat to the Magdalen islands—a rather rough passage in a light round bottom boat.

Primary stations, coincident with Hydrographic Survey stations, were located on each of the three main islands, Entry, Amherst and Grindstone. They are on the summits of steep bare hills, the highest being on Entry island, and having an elevation of 580 feet. Positions of lighthouses at Grand Entry and Brien island and a signal on Deadman island can be readily obtained from the primary stations.

The remainder of the season was spent in the north of Cape Breton. This section of the country is very rough and rugged. Very steep hills rise almost from the shores and attain heights of from twelve to fifteen hundred feet. The interior is mostly barren land with few prominent points, and the water courses form very deep ravines.

Primary stations on the north west coast, were located at Grand Etang and Cap Rouge. These stations connect with Cape Mabou, with Prince Edward island and with the Magdalen islands. On the opposite coast stations were located as far north as "Franey" at Ingonish. Three stations in the north interior have yet to be visited.

It is hoped that Franey and Cape North will be connected with points in Newfoundland. Observations from these points will probably have to be made very early in the spring, as it is doubtful if weather conditions will permit observing there at any other time.

Transportation during the season was effected by means of a Chevrolet car, which was sold at the close of the season. This car had been in operation for three years. It had been run over 20,000 miles and had given good satisfaction.

All elevations were obtained by aneroid barometers, and it is recommended that in future engineers be supplied with aneroids having thermometers attached.

PRECISE LEVELLING IN 1921

F. B. Reid, *Supervisor of Levelling*

Five parties were in the field, in charge of Messrs. McMillan, Raley, Smith, Sinclair and Dalton. The first two of these were engaged in the prairie provinces, the third in British Columbia, the fourth in Northern Ontario and the fifth in Central and Northern Ontario.

Detailed reports by the Chief of each party will be found below.

The mileage run by each engineer is shown in the following table, also the percentage of relevelling, the number of standard bench-mark piers built and the total number of bench-marks established, including piers:—

Engineer in charge	Mileage levelled	Percentage Relevelled	Piers built	Total B.Ms. established
D. McMillan	157	26	27	31
G. S. Raley	266	22	44	67
N. H. Smith	287	13	29	83
G. E. B. Sinclair	275	7	12	124
G. F. Dalton	252	20	9	79
	1,237	.....	121	384

Of the 266 miles levelled by G. S. Raley but 55 miles was new work, the balance being rerunning of old work. In the case of G. F. Dalton also, 41 miles of the season's total was rerunning of levelling done in former years. This leaves a total of 985 miles of new levelling accomplished this season.

The following is a summary of the new levelling done in 1921:—

Line	On railway	Off railway	Total
Swift Current, Sask., to International Boundary	44·0	80·7	124·7
Empress, Alta. to Alsask, Sask	0·0	32·1	32·1
Portage-la-Prairie to Plum Coulée, Man	54·0	1·5	55·5
New Hazelton to Prince George, B.C	287·0	0·0	287·0
Jacobs to Kabina, Ont	274·8	0·0	274·8
York River to Whitney, Ont	30·1	11·8	41·9
Romford to Latchford, Ont	166·6	2·4	169·0
	856·5	128·5	985·0

Previous to 1921, 14,031 miles of levelling land had been accomplished; the total to date is therefore 15,016.

Three hundred and eighty-four bench-marks have been established this year, which brings the total number at the present time to 4,544—not including those of other organizations which have been connected with the levelling of the Geodetic Survey of Canada.

The mileage of the levelling since the beginning of the work is distributed among the provinces as follows:—

Province	Previous to 1921	1921	Total
Ontario	4,102	486	4,588
British Columbia	1,781	287	2,068
Saskatchewan	1,793	157	1,950
Quebec	1,776	0	1,776
Alberta	1,481	0	1,481
Manitoba	982	55	1,037
New Brunswick	864	0	864
Nova Scotia	705	0	705
Yukon Territory	458	0	458
Minnesota, U.S.A.	89	0	89
Total	14,031	985	15,016

It is distributed among the railways as follows:—

Railway	Previous to 1921	1921	Total
Can. National-Grand Trunk	6,675	592	7,267
Canadian Pacific	5,441	117	5,558
Great Northern	176	54	230
Algoma Central	219	0	219
Dominion Atlantic	146	0	146
Quebec Central	109	0	109
Timiskaming and Nor. Ontario	0	94	94
White Pass and Yukon	91	0	91
Temiscouata	82	0	82
Ottawa and New York	55	0	55
Pere Marquette	55	0	55
Maine Central	36	0	36
Boston and Maine	34	0	34
Napierville Junction	28	0	28
British Columbia Electric	28	0	28
Que. Ry. Light and Power Co	25	0	25
Pacific Great Eastern	9	0	9
Michigan Central	3	0	3
London and Port Stanley	2	0	2
Highways and cross-country levels	817	128	945
Total	14,031	985	15,016

D. McMillan reports as follows on Precise Levelling in Saskatchewan.

On April 25 the writer left Ottawa and proceeded to Swift Current, Sask., where a party (7 men) was organized and equipped. A day was spent in setting up camp, adjusting instruments and instructing new assistants in their duties.

Starting at Swift Current on May 2, a line of precise levels was run southeast along the Canadian Pacific railway to Vanguard; thence south across country to the International Boundary, terminating on a bench-mark of the United States Coast and Geodetic Survey in the base of Boundary post No. 486, about 6 miles west of the 107th Meridian. Connections were made with two of the Topographical Survey bench-marks in the vicinity of Aneroid, Sask., near which place the respective lines cross. On completion of this line, on August 20, the party moved to Empress, Alberta, from which place a line was run north along a road allowance to Alsask, Sask., closing upon a bench-mark of the Topographical Survey Saskatoon-Calgary line.

Both of these lines were run across very rough, hilly country, necessitating as many as twenty-five sights to a mile in some cases. Consequently progress was comparatively slow and the percentage of relevelling higher than usual. Throughout the season the discrepancies between forward and backward levelling showed a decided tendency to the sign minus and it was sometimes found necessary to relevel sections between temporary bench-marks which were themselves within the allowable limits of error in order to reduce the accumulated discrepancy between permanent bench-marks. Early in the season it was thought that this tendency might be due to the turning pins (rod supports) sinking slightly each time the rods were placed upon them; but repeated tests, at different times, failed to prove that such was the case.

When levelling along the railway between Swift Current and Vanguard, the usual procedure was followed and the party travelled by railway motor car. The balance of the season's work being along country roads and trails, it was found essential to modify the ordinary programme in some respects, and a one-ton motor truck was used for transportation purposes.

Bench-mark piers were erected on the road allowances about 6 miles apart. In the southerly portion of the Vanguard-International Boundary line considerable difficulty was experienced in finding suitable gravel within a reasonable distance for the construction of the concrete piers. That district being sparsely settled, there are very few gravel pits opened up, so that we had to discover and open them for ourselves.

The new rods, graduated to hundredths of a yard instead of hundredths of a foot, were found very satisfactory. One noticeable feature is that they can be read distinctly at a greater distance than the type formerly used. Experiment shows, however, that best results are obtained by adherence to the old length of sight.

While engaged in the levelling of the line Empress-Alsask, the party was in constant communication with Mr. Barton, one of the engineers of the Reclamation Service. He was making a topographic survey of that district to ascertain its possibilities from the viewpoint of irrigation. For this purpose he considered that if the elevations of the Geodetic Survey of Canada were available they would form a valuable basis for that work. Realizing the importance to the country of the work in which he was engaged, and also the advantage our figures would be to him, the writer was very glad to give him, from time to time, results of levelling through the district.

In the course of the season's work 31 permanent bench-marks were established, 27 of which are in concrete piers and the balance in the masonry of public buildings of a substantial nature.

Work was discontinued and the party disbanded at Alsask, Sask., on October 4. The next work to be undertaken would have required at least six weeks to complete and experience has shown that in this country precise levelling cannot as a rule be carried on successfully or economically later than the month of October. This applies particularly to the northerly portion of the Prairie provinces.

G. S. Raley reports as follows on precise levelling in Manitoba and Saskatchewan.

Having received instructions to complete the line of precise levels from Portage-la-Prairie to Plum Coulée, Man., commenced in October, 1920, the writer left Ottawa on April 29 and proceeded to Portage-la-Prairie. As the line had been carried about six miles out of town the previous fall, camp was first made at Carman instead of Portage-la-Prairie. Before commencing levelling, all bench-marks on the line were established—sixteen of which were bench-mark piers.

Gravel and sand had to be purchased and hauled to pier sites. This was done by means of railway motor car and trailer. Water was available at all points along the line and no difficulty was encountered in that respect. Connection was made with the bench-marks Nos. 5-C and 6-C near Plum Coulée; No. 4-C was unfortunately found to be destroyed, the top with the copper bolt being knocked off. This pier was dug up and examined—having been built in soil slightly alkaline. It had been established in 1912 and on examination it was found that the part of the pier below ground was in excellent condition; the upper part which had been exposed to the air was

weathering away. This was not due to alkali water which was probably used in construction, but from lack of enough cement in the mixture. The other piers, 5-C and 6-C, built the same year, were in very good condition and showed no sign of weathering or disintegration.

The relevelling on the line was excessive, amounting to about 40 per cent. It was thought at first this was due to unfamiliarity with the new (yard graduation) levelling rods, but the relevelling still continued high at the end of six weeks' work. From the results it is evident that quite a lot of it was caused by temporary bench-marks shifting as the frost came out of the ground.

On July 11 the engineer moved away from this district and started from Swift Current, Sask., rerunning the line to Moose Jaw which was originally levelled in 1912. This line was not very well provided with bench-marks in the first instance and moreover several of those established were destroyed or rendered inaccessible by the double-tracking of the railway. As there is no parallel line of railway in the neighbourhood which could be utilized for a new line of levels it was desired to have an amply sufficient supply on the Swift Current-Moose Jaw line and to this end 33 additional bench-marks were established, including 18 piers. At the same time the accuracy of the original work was confirmed. The rerunning consisted in part of standard forward and backward levelling and in part of levelling in one direction only.

On completion of the above work the party moved to Regina and spent the balance of the season rerunning the Regina-Melville line of levels. The study of closures of adjoining circuits had led to the belief that there was some inaccuracy in the original running of this line and it was desired to ascertain the trouble. Standard forward and backward levelling was carried right through to Melville and the final elevation of the terminal bench-mark altered by 0·51 foot. While the rerunning was in progress twelve additional bench-marks were established at selected points.

The last levelling was done on November 16 and the outfit was then stored at Melville and the party disbanded.

The weather at the beginning of the season was not very suitable for levelling, considerable wind and rain being experienced. Later on, during June, the heat was excessive, culminating in a thunderstorm on July 1 which blew down all the tents. In the early fall again the rainfall was excessive, but the latter part of October was ideal for levelling. The weather in November was very cold and stormy as might be expected and some difficulty was experienced in pushing the line through to Melville.

N. H. Smith reports as follows on precise levelling in British Columbia:—

On May 6 the writer left Ottawa with instructions to run a line of precise levels along the Canadian National railway from New Hazelton to Prince George, B.C.

The engineer arrived in Edmonton on the 8th and stopped over there to hire a cook and order a supply of provisions.

Mr. Lowndes, assistant, arrived in Hazelton on May 10. The other members of the party having been instructed to meet him on that date, camp was immediately set up and the railway motor car put in order for the season's work.

The party reached Hazelton on May 12 and started levelling the following day. After instrument and rod level adjustments were made, the distance between last year's bench-marks 226-H and 227-H was re-levelled and the elevations were found to be unchanged. On May 14 the season's levelling was started at bench-mark 227-H and continued throughout the rest of the season along the line of the Canadian National railway to bench-mark 162-H at Prince George.

During the course of the season 83 bench-marks were established, 29 of which were in concrete bench-mark piers. Material for the construction of piers was in most cases quite convenient, that is to say, it was always close to railway right of way and only necessitated a haul of a few miles on track car, at most. Twelve bench-marks were placed in rock surfaces, other than cuts; 10 were placed in rock cuts; 10 in water tanks; 11 in bridges; 8 in public buildings; 2 in tunnels and 1 in a culvert.

The weather was for the most part cold and wet, but though a great deal of rain fell, very little time was lost on this account, as it was mostly a light rain and did not interfere with levelling operations to any great extent.

Thirteen per cent of the work had to be re-levelled. Owing to the change in graduation of rods, from feet to yards, the amount of re-levelling was slightly larger than in the past, but this was more than compensated by the observer being able to take longer sights during the time of day when the refraction was bad.

Eight camps were made during the season, namely, Hazelton, Smithers, Houston, Burns Lake, Endako, Vanderhoof, Nichol and Prince George. A move of from 35 to 40 miles was found to be the most convenient, though in some cases a longer move was necessary.

This season's work connected up the gap between Hazelton and Prince George and completed our line of levels along the Canadian National Railway. Connection was made with previously established bench-marks at both ends of the run. These bench-marks, upon inspection and checking, were found to be in a good state of preservation and their elevations unchanged.

The season's work consisted of 287 miles of new levelling and about 6 miles of check levelling of previous work at the two ends of the main line of levels.

Levelling on this line was finished on September 26 and the party partially disbanded on the 28th and on the same day the engineer went to Prince Rupert, taking with him four members of the party, to establish two bench-marks in a rock cut, close to the Naval Service Department's reference bench-mark, as the Geodetic Survey bench-mark previously established for this purpose is now inaccessible. The levelling previously done in Prince Rupert and vicinity was also checked. The elevation of the bench-mark pier just outside of Prince Rupert was found to have changed slightly, this being due undoubtedly to the pier having been built on made ground.

A marked saving of time was made this season by having the assistant go ahead of the levelling party, accompanied by one man, to put in, describe and sketch bench-marks before the arrival of the main party.

G. E. B. Sinclair reports as follows on Precise Levelling in Northern Ontario:—

Messrs. Thoburn, Perrier and Herriot left Ottawa on May 7, while the recorder, Mr. C. C. Ross, the cook and engineer left Winnipeg on May 8. The members of the party, along with the pilot supplied by the Canadian National Railway, assembled at Jacobs, Ont. on the morning of May 9.

The instructions stated that the party was to carry the line of Precise Levels eastward from Jacobs along the Canadian National railway. This line of levels had been commenced at the junction of the Canadian Pacific and Canadian National railways near Rennie, Man., in May 1920, and had been extended as far as Jacobs, Ont. by September 1920.

Levelling was commenced on May 10 and carried eastward over the Armstrong, Grant and Hearst subdivisions of the Canadian National railway to a point twenty miles west of Hearst. The total number of miles double-levelled was two hundred and seventy-five. This was acomplished in four months and seven days, the party disbanding on September 17.

In the first thirty-five miles of the season's work we had between 20 and 25 per cent re-levelling. This is credited to the taking of sights which were too long for the use of the new rod which is graduated to yards. By reducing the length of sight to that formerly taken with the old "foot" rod—or slightly less—the re-levelling was practically nil. In the last one hundred and thirty miles of the season's work every mile section was within the required discrepancy limit. It was thus possible to reduce re-levelling to 7 per cent for the season.

The country traversed this season is probably the most sparsely settled territory along the Canadian National railway east of Winnipeg. Freight train service was very irregular; sometimes a wait of a week for a train to move our camp outfit

resulted only in having to move by motor car. The railway motor car was an indispensable part of our equipment. During the season eleven camps were made at only four of which post offices existed.

There were 124 bench-marks established during the season, which may be classified as follows:—

Standard bench-mark piers	12
Rock surfaces	15
Concrete footings of railway water tanks	13
" abutments of railway bridges and culverts	79
" foundations of buildings	5

Great care was exercised in the selection of bench-mark locations and all established bench-marks should be most reliable.

There was considerable wet weather throughout the season. The effect of this was two-fold, the slowing up of the work and the breeding of black flies and mosquitoes.

The Canadian National Railway employees, from Superintendent W. B. Way, down, gave every possible assistance.

G. F. Dalton reports as follows on precise levelling in Central and Northern Ontario:—

According to instructions received the party left Ottawa for Maynooth, Ont., on the night of May 8. Precise levelling operations were commenced on the 13th at York River Junction, Ont. From this point the Canadian National railway was followed northwesterly to the end of steel at Wallace, Ont., and thence overland to L'Amable creek and No. 1 camp of the Dennis-Canadian Lumber Company. The railroad of this lumber company was then followed northerly to Whitney, Ont., where a connection was made with G.S.C. bench-mark 536 (1914 levelling). By the completion of this line of levels the large circuit Tweed-Bancroft-Lindsay-Coldwater-Parry Sound-Renfrew-Sharbot Lake-Tweed, was cut practically in two and the closing error almost equally divided between the two smaller circuits thus formed.

Owing to a defective instrument having been used on the first 32 miles of the above work, relevelling was excessive, amounting to 18 miles out of the 32, or approximately 56 per cent. The defects in this precise level No. 626, could not be rectified in the field and it was therefore returned to the office as soon as another instrument was sent out to replace it. Thereafter, till end of season, level No. 388 was used and relevelling was kept within reasonable limits.

On completion of the above work on June 22, relevelling was commenced on the Grand Trunk railway, which covered the 1914 levelling from Whitney, Ont., to Barry's Bay. All thirteen of the old bench-marks on this line were connected with and two additional ones established. Work was completed on July 13.

On July 15 the party entrained at Whitney for Sudbury, Ont., arriving on the 16th. Work was shortly afterwards commenced on the Canadian Pacific railway. The section between Sudbury and Romford was relevelled, i.e., from bench-mark 454 through bench-marks 453 and 452 to bench-mark 451. The results obtained indicated a movement in the two first-mentioned bench-marks since they were originally established.

Levelling was then carried along the Canadian Pacific railway from Romford to North Bay, a distance of 72 miles—the levelling being based on bench-mark 451. This line was completed on September 2nd.

At North Bay connections were made with two bench-marks of the Department of Public Works and four bench-marks of the Geodetic Survey were established in this town.

Levelling was then continued along the Timiskaming and Northern Ontario railway and extended northerly as far as Latchford. Owing to unfavourable weather conditions—snow, high winds and cold—work was discontinued for the season at Latchford on November 13. Along this line connections were made with nine bench-marks of the Department of Public Works, the last of which is at Latchford.

On the 14th camp was taken down and the outfit stored at Cobalt. A portion of the party was disbanded and the remainder made a side trip to Sudbury. Here the sections 454 to 454-A and 567-A (1912 levelling in Sudbury) were relevelled in order to further verify the results of the relevelling which was done in this vicinity earlier in the season. This was completed on the 16th and the remainder of the party was then disbanded.

The weather during the season was fairly favourable. Throughout the whole of the month of July the heat was quite extreme.

The following is a list of the camps occupied during the season:—

Maynooth, Wallace, Whitney, Sudbury, Warren, North Bay, Tomiko, Timagami, and Cobalt.

There were 79 bench-marks established during the season, which may be classified as follows:—

Standard bench-mark piers	9
Rock surfaces	45
Bridges and culverts	20
Buildings	5

REPORT SUBMITTED BY F. A. McDIARMID, 1921-22

1. Geodetic Astronomy.
2. Standards.
3. Base Line and Precise Traverse.
4. Canadian Arctic Expedition.

1. GEODETIC ASTRONOMY

Two of the triangulation stations of the Geodetic Survey of Canada were occupied as Laplace stations during the past season. These were West Base, Anticosti island, and Derby, in Cape Breton island, N.S. The azimuth of a line Cap-Chat to Castor was also observed from Cap-Chat completing the Laplace observations at that station. The azimuth of the line Cap-Chat to Mechins had been observed the previous year but the horizontal circle of the instrument used had been injured, and the observations were very irregular, and it was thought unreliable. However a reduction of the observed azimuth of the line Cap-Chat to Mechins to the line Cap-Chat to Castor by applying the observed angle at Cap-Chat subtended by Mechins and Castor showed a difference of less than one-tenth of a second of arc, from that obtained from the direct observations on Castor from Cap-Chat. In both sets of observations thirty-two positions of the circle were used. This agreement tends to show how a very defective circle will give a reliable result when pointings are taken in a great many positions of the circle.

The astronomical station on Anticosti island is at the west end of the base line; an ordinary concrete pier was built for the support of the astronomical transit. The Telegraph connection to Ottawa was established by means of the Canadian National Telegraph from Ottawa to Ellis Bay, Anticosti island via the main line, Ottawa to Quebec; the line along the south shore of the St. Lawrence, Quebec to Gaspé; a cable, Gaspé to South West Point Anticosti island; and a land wire, South West Point to Ellis Bay. From Ellis Bay to the observatory an old telephone wire was utilized. The electric power for this long circuit was supplied by the regular line batteries at Ottawa, Montreal, Quebec and Gaspé. Part of this line, Ellis Bay to Gaspé, is generally used locally with a small battery at Gaspé, and when this wire was connected through from Ellis Bay to Quebec it was found that there was not sufficient power to drive the Ellis Bay signals to Quebec. A hundred dry cells, installed at Ellis Bay, still seemed inadequate, and finally a small battery of fifteen dry cells put on at the observatory at West Base proved ample to send the signals to Ottawa with sufficient

force to register on the instrument there. An exchange of signals between Ottawa and West Base was attempted every night from July 15 to July 26, and on eight of these nights a complete exchange was obtained. On some of the nights smoke slightly dimmed the stars, but did not interfere with the successful completion of the time sets.

The azimuth of the line West Base to East Base was observed. The distance from West Base to East Base is about eight miles, part of the distance, about one mile, is through a vista cut through the timber; the rest of the distance is over open clearing. Observations for azimuth were obtained on two nights, August 4 and 5. The latitude was also determined from observations made on twenty pairs of stars by the Talcott Zenith Distance Method.

The Derby triangulation station is situated on a high hill overlooking Bras d'Or lakes. It is about one and a half miles from the Grand Narrows station of the Canadian National railways. Longitude, latitude and azimuth were observed at this station. The wire connection for the exchange of time signals with Ottawa was made over the Canadian National Telegraph, a loop having been built from the railroad station at Grand Narrows to the geodetic station. Observations for longitude were commenced on August 10, and completed on August 17, five complete determinations being obtained. The azimuth observations on the line Derby to Crowdis were taken on the nights of August 17, 19 and 21, and observations were made in thirty-two positions of the instrument. A latitude determination was made from twenty-five pairs of stars using Talcott's Zenith Distance Method.

Observations were made for the values of the personal equation both before the West Base and after the Derby. The values for personal equation were ·062s and ·058s respectively. The mean ·060s, was adopted for the season and applied to the observed difference of longitude.

The latitude and azimuth observations were reduced in the field and later checked in the office by Mr. F. W. O. Werry who also made the preliminary computation of the longitude and personal equation observations.

The probable errors of the several azimuth results are about $\pm$·″15 and the longitude differences in stations have a range of about five hundredths of a second of time.

2. STANDARDS

The work carried on during the past year in connection with the Geodetic Standards of length is divided into two parts; first, the intercomparison of the metre bars and the standardization of the five fifty-metre invar base line tapes; and second, observations made on the graduations of the six pairs of precise level rods of the Geodetic Survey of Canada.

In May and June previous to the measurement of the Anticosti base line the three base line tapes Nos. 3139, 3140 and 3141 were intercompared with the reference tape No. 4252 the length of which had just been determined from the standard nickel bar No. 10239. The length of the fifty-metre invar tape No. 13814 was also measured by a comparison with tape No. 4252. This tape was used by Mr. Riddell on his precise traverse work near Hamilton, Ontario. Comparisons of the several lengths of these five tapes from year to year show that their lengths are remaining fairly constant, also there are still small variations from time to time. These tapes are now about ten years old and hence are becoming very valuable. It is absolutely necessary that the greatest care should be exercised in using them, and also in standardizing. Too much emphasis cannot be placed on the fact that these tapes must be standardized in the same way as used in the field. The Ordinance Survey of England in speaking of this very point says that all the apparatus, namely pulleys, weights etc., which are used in the field must be used when standardizing. Also Professor Glazebrook in correspondence with this office a few years ago said that he had never known an invar tape which behaved in a regular way and laid particular emphasis on the need of standardization especially before and after measuring a base line.

The use of wooden rods for precise level work has been occupying the attention of this office for the last two years. In order to test the constancy of length of such rods throughout a whole season and under all conditions of humidity, it was decided to make observations on the six pairs of rods of the Geodetic Survey throughout the summer of 1921. The full results of all these observations will be treated in a special publication to be issued on this subject. It should just be mentioned here that the observations taken amply justify the conclusion that wooden rods, however well prepared by boiling in paraffin, do not hold their lengths sufficiently well for precise level determinations. Strips of some metal, preferably invar, with a low co-efficient of expansion should be used. The observations made on these rods indicate that the lengths are functions of the moisture of the atmosphere. When the air is dry the rods contract, and when the air is humid the rods expand.

3. BASE LINE AND PRECISE TRAVERSE

The Base Line and Precise Traverse work was carried out by two field parties, the base line party under charge of Mr. K. H. Robb, Junior Geodetic Engineer, and the precise traverse party under Mr. J. M. Riddell, D.L.S., Geodetic Engineer in charge. Mr. Robb has had wide experience in base line work, and the accuracy of the results obtained speak volumes for its high standard. The precise traverse is a new departure of the Geodetic Survey of Canada. Mr. Riddell with a very small party covered a great distance, and the smallness of the error of closing, namely one in approximately one hundred thousand indicates its great success. Mr. Riddell in his personal report is dealing in detail with the various phases of precise traverse work.

The Anticosti island base line as intimated in last year's report is near the north west end of the island. The base line lies in part along the railroad which had been built by the Anticosti Island agency for the purposes of transporting the timber from the centre of the island to the mills at Ellis Bay. The total length of the base line is nearly eight miles or twelve and a half kilometres. The west end of the base is on a wooded hill just north of mile post ten. This end of the base was used as a Laplace station. There was approximately one and a half miles of timber cut along the whole line. The clearing, posting and measuring was done by a party of ten men under the direction of Mr. Robb. The party reached the scene of work on Saturday, June 11, and the whole work was completed on Saturday, July 30, exactly seven weeks. When it is considered that the whole base had to be cleared of logs and undergrowth, that on part of it the timber had to be cut, scaffolding built over swamps, concrete posts put in as permanent marks, posts prepared, and the whole line posted and measured, the completion in forty days with an untrained party is an achievement of no mean order.

The grades along the base were small in most cases, only in a few places were there differences of elevation of more than ten feet. The total grade correction for the whole twelve kilometres base was only 3·3 metres.

The method used in measuring is described in detail in the 1919-20 report on the measuring of the Fort Rupert base. It might however be of interest to refer briefly to the splendid agreement of the several measures in the different kilometres. On only one or two kilometres was the difference between the lengths as determined from the different tapes greater than on millimetre. In order to obtain the correction for grades a line of levels was run over the tops of the posts, and in order to get the altitude above sea-level the levels were continued from the point where the base line crosses the railroad track, along the railway to Ellis Bay where a tie was made to the mean sea-level. A number of bench-marks were put in at convenient places. These will serve for future reference.

4. CANADIAN ARCTIC EXPEDITION

The work on the maps of the Canadian Arctic expedition has been continued, and preliminary maps showing the discoveries of the different years of the expedition

have been prepared and handed over to the department of the Naval Service; also copies were sent to Mr. Stefansson for use in his book "The Friendly Arctic." The preparation of the materials for a large scale map showing the trails, traverses, etc., of the expedition in detail is now in progress. Mr. T. H. Parker, Geodetic Engineer, has charge of this work.

List of Publications of the Geodetic Survey of Canada, 1922

Publication No. 1—Precise Levelling—Certain Lines in Quebec, Ontario and British Columbia.

Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.

Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.

Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.

Publication No. 5—Field Instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.

Appendix No. 1 of Publication No. 5—Instructions to Lightkeepers on Primary Triangulation.

Publication No. 6—Precise Levelling—Certain lines in Manitoba and Saskatchewan.

Publication No. 7—Geodetic Position Evaluation.

Publication No. 8—Field Instructions for Precise Levelling.

Publication No. 9—The Making of Topographical Maps of Cities and Towns, The First Step in Town Planning.

Appendix No. 4, Publication No. 5—Instructions to Lightkeepers. Use of Electric Signal Lamps.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921.

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